Effectiveness of using biographical sketches in the teaching of high school chemistry

Ronald Ray Easter
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EFFECTIVENESS OF USING BIOGRAPHICAL SKETCHES IN THE
TEACHING OF HIGH SCHOOL CHEMISTRY

by

Ronald Ray Easter

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY
Major Subject: Vocational Education

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1956
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I. INTRODUCTION

Chemistry instruction in the public high schools of the United States can be traced back to the early high schools. Serious consideration to issues concerning the objectives, the course content and the methods of chemistry teaching is a phenomenon of the 20th century. Many studies have been made by teachers and research workers and many more exploratory innovations have been undertaken to evaluate certain of these issues which are encountered by chemistry teachers.

Any promising attack of these issues in the teaching of high school chemistry must be made in terms of changing conditions during the past five decades, i.e., (1) the choice of content from an ever-expanding chemical knowledge; (2) the change in the high school population; (3) advancements in the psychology of learning; and (4) the purpose of an introductory course in high school chemistry.

Knowledge in many fields of chemistry has increased rapidly with no reason proposed to indicate that this increased trend will diminish in the future. This increase in total chemical knowledge has resulted in changing the content of high school chemistry courses during the past fifty years, as an inspection of older and more recent high school chemistry textbooks will reveal. Constant revision of textbooks from the standpoint of content is necessary if the needs of students are to be considered. It is apparent that such revisions cannot represent the expansion of content because, in the past or in the foreseeable future, the amount of class time devoted to a course in high school chemistry
has remained, and will continue to remain, reasonably constant.

The change in high school population during the past few decades has been phenomenal. At one time, completion of elementary education represented the socially acceptable standard for a potential citizen in most communities. High school education, if undertaken by a youth, was justified only as preparatory to college education to the end that the youth expected to enter medicine, law or some other of the so-called learned professions. A gradual change in community mores took place to the point that high school graduation became the badge of community acceptance of a youth. It may be that community mores are approaching the point that college attendance, or perhaps college graduation is necessary lest a young man or young woman feels an inferiority complex in the social situation in which a youth is plunged.

The extent to which any given youth proceeds in the education ladder is known to be a function of the economic level of his parents, of his own academic aptitude and of the mores of the community from which he comes or of the community to which he anticipates migration. The relative motivation for additional education resulting from parent economic level, from academic aptitude and from community mores, so far as known, has not been studied. The relative motivation, no doubt, varies from community to community and from time to time as revealed in periods of depression and prosperity.

It has been, and probably will always be, possible for a youth to continue his educational career regardless of the economic status of his parents. There remains, nevertheless, a tendency at the high school level for the extent of formal education to be related to economic level
of parents.

Regardless of the underlying cause, the high school population has been increasing rapidly over the past fifty years and, from all indications will continue increasing, particularly, in the immediate future. The trend in quality, from the standpoint of scholastic aptitude, is an issue beyond the scope of this study.

Prominent among the points of view with regard to the psychology of learning, reflected in high school instruction during the past fifty years, are (1) faculty psychology, (2) S-R bond theory, (3) behaviorism and (4) gestalt psychology. Probably few teachers adhere exclusively to any one of these four points of view. Instruction in chemistry reveals that most teachers during this period have had an eclectic point of view concerning the psychology of learning. This eclecticism, however, has not been constant during the last fifty years, the place of faculty psychology decreasing and the place of gestalt psychology increasing.

More important than the changes in point of view with regard to the psychology of learning, perhaps, has been the rapid increase in providing devices designed for improving instruction such as chemistry clubs; visits in industrial plants; guest speakers; special reports by students; use of slides, radio and television; and many others.

In recent years, the issues arising from a consideration of the purposes of an introductory chemistry course have received much attention. Numerous opinions have been expressed concerning the content of an introductory course in chemistry for students for whom such a course terminates chemical instruction as contrasted to students for whom the course serves as a first step toward later sequences in chemical
instruction. The former is usually referred to as chemistry for general
education.

Proponents of general education tend to feel that an introductory
chemistry course should be of interest to and designed to meet the needs
of future business men, farmers, housewives and other groups who there­
after will receive no additional formal chemical instruction. Opponents
of general education tend to hold to the viewpoint that the content of
an introductory course suitable for students who later will receive
additional instruction is equally suitable for students for whom an
introductory course is terminal.

It may be that the tendency to classify students into the suggested
dichotomy is an oversimplification. Most high school chemistry teachers
can identify among their students several groups. Two groups of students,
who do not intend to go to college will later enter vocations some of
whom do rely on, and others do not, a background of chemical education.
Several groups of students may be differentiated among the college-bound
high school chemistry students such as, those who would like (1) to major
in some area in which no science will be required; (2) to major in some
area in which little science will be required; (3) a nonscience major
with a science minor; (4) to major in some science other than chemistry;
and (5) to major in chemistry.

It is probable, that most high school chemistry teachers believe in
the principle that instruction should be based upon the needs and
interests of the individual students. If these needs and interests were
uniform for all students, most of the debatable issues confronting high
school teachers would cease to exist. Lack of such uniformity demands
that a teacher modify instruction to some extent required for group instruction in public education.

The study here reported was conducted in the chemistry classes in the high school of Ames, Iowa. A description of the community and the high school will be presented later yielding some evidences of the possibility of interpreting the findings and conclusions to other public high schools.

The investigator was the instructor of all chemistry classes included in the study. Although some supplementation was provided, the content of the course may be inferred from an inspection of the textbook used JAFFEE, BERNARD New World of Chemistry, Silver Burdette Company, 1947. Instructional implementation was provided by demonstrations; individual laboratory work; an occasional guest speaker; occasional field trips; special reports by students and the frequent use of audiovisual aids.

The purpose of this study was to evaluate the usefulness of greater emphasis than usually prevailing in conventional chemistry courses upon biographical sketches. Increased emphasis upon men and events in chemistry has been advocated for many years, as a review of science education periodicals reveals. This advocacy has been based sometimes upon speculation and, at other times, on exploratory attempts to include an increased amount of course content about men and events. Reports of such innovation have relied largely upon subjective judgment of effectiveness. This study has been designed to assemble objective evidences of the desirability of including an increased emphasis upon men and events in an introductory high school chemistry course.
Any satisfactory evaluation of the effectiveness of instruction should be made in terms of the important objectives of that course. The objectives of a high school course in chemistry, and especially their relative importance, differ from teacher to teacher. No attempt will be made, in this study, to appraise the relative importance of the objectives chosen.

The objectives included in this study have been chosen to some extent because of their traditional acceptance of importance and, to some extent, because of the feasibility of obtaining objective measurements. The effectiveness of instruction in a high school chemistry course, for purposes of this study, is defined in terms of the following six objectives, described in more detail in the later reported evaluation of each.

1. Fundamentals of High School Chemistry
2. Men and Events in Chemistry
3. Scientific Method
4. Scientific Attitude
5. Scientific Interest
6. Science Activities and Ambitions

The confidence which can be placed in the findings and conclusions for each of the objectives must be justified in terms of the suitability of the chosen instrument of its evaluation.
The origin of chemistry is lost in the mystery of the alchemist. Although alchemists laid the foundation of chemistry by observing what happened while heating, distilling and combining— it was part of their system to remain, as far as possible, aloof from what is presently called chemical education.

In ancient Greece, chemical education received but little attention. Although the alchemists taught less than they knew, the Greeks taught more than they knew. Thales is remembered by chemists for his statement that water is the origin of all things. Moore\textsuperscript{1} reported that "Democritus (460-370 B.C.) taught, according to Aristotle, that atoms are hard and have form, size and weight." Aristotle taught the difference between matter of a substance and something else he called the essence. Aristotle conformed to the spirit of the times by teaching untested ideas and by getting abstract qualities confused even with elements such as blackness for carbon.

Records have not established whether alchemy began in Egypt or China. It existed before, during and long after the rise and fall of ancient Greece. Thorpe\textsuperscript{2} reported that "Chemistry, as an art, was practiced thousands of years before the Christian era; as a science it

\begin{enumerate}
\end{enumerate}
dates back no farther than the middle of the seventeenth century*.

The Arabs are frequently referred to in alchemical literature. They conquered Egypt in 640 A.D. and found books on how to make gold and cure ills. For the next hundred years books were translated into the Arabic. In the course of history the Egyptian knowledge reached Europe when Latin translations were made of the Arabic books. The Arabs are now thought to have been users but not originators of alchemical information.

Roger Bacon, a thirteenth century chemist, might be considered a chemist's alchemist. He was a recognized alchemist but was an avid experimenter in the scientific sense. He made use of and taught the inductive method of learning and did not subscribe to the unintelligible writing associated with alchemists even into the sixteenth century.

As late as the seventeenth century, chemistry was so tied to alchemy it lagged behind physics and astronomy. Beginning with Robert Boyle (1627-1691), in England, men emerged who were interested in chemistry in a devoted and scientific way.

It is interesting to note that the opening of the American historical frontier coincided approximately with the opening of chemical frontiers. By the time the Colonies were settled enough to be concerned with chemical education, chemistry was engaged in a struggle between the phlogiston theory and the modern theory of burning. In an astonishing chain of events chemical education in the United States grabbed Lavoisier's oxidation theory of burning and swept upward with it. The review of literature which follows has been limited to chemical education in the United States.
A. Beginning of Chemical Education in the United States

To educate their young people, earliest settlers in the United States naturally copied the schools of Europe. Important differences developed, however, which were due to the selection of individuals who made the hazardous trip across the Atlantic. An extreme desire to break with tradition provided the motivation that caused certain individuals to pioneer in the new world. From ordinary beginnings, breaks with tradition were soon evident in chemical education.

Conventional chemical industries were started early, in fact the manufacture of glass was begun in Jamestown soon after the landing of the Pilgrims. John Winthrop, Jr. came to Boston in 1631 and organized chemical industries in iron and salt. He continued work in industries related to chemistry until he has been called "the first American chemist and forerunner of chemical education in America".¹ Winthrop had a dual interest; in chemistry itself and in its relation to medicine.

Chemical education in the United States began specifically when physicians outgrew the giving of individual instruction to future young doctors. Medical doctors who had studied in Europe started medical schools. These well-organized schools formed a foundation that nurtured chemical education.

An example of early formal chemical education and its connection

¹NEWELL, LYMAN C. "Chemical Education in America from the Earliest Days to 1820." Journal of Chemical Education. 9: 677; April 1932.
with medicine may be found in the University of Pennsylvania. Hepburn\textsuperscript{1} reported, "At the University of Pennsylvania, chemistry was taught to college students by Provost William Smith at least as early as 1756, and to students in medicine by Dr. John Morgan upon the institution of the department in 1765".

Chemistry was offered in several colleges in the United States before 1800. In 1767 James Smith, M.D., became professor of chemistry and materia medica at the newly opened medical school of King's (later called Columbia University) College. Newell\textsuperscript{2} said Benjamin Rush was the first man to teach only chemistry in a regularly appointed position. He taught chemistry in 1769 at the Philadelphia Medical School (University of Pennsylvania). Hepburn\textsuperscript{3} furnished evidence that Rush replaced Dr. John Morgan who taught chemistry for four years before Rush was appointed.

Newell\textsuperscript{4} pointed out that Benjamin Rush was a great salesman for chemistry in the new world. Besides being a recognized scientist, (student in Edinburgh for 2 years) Rush was a signer of the Declaration of Independence and in 1799 served as Treasurer of the United States Mint. Rush's book, \textit{Syllabus of a Course of Lectures on Chemistry} was

\begin{quote}
\textsuperscript{1}HEPBURN, JOSEPH SAMUEL. "Notes on the Early Teaching of Chemistry in the University of Pennsylvania, The Central High School of Philadelphia and the Franklin Institute of Pennsylvania." \textit{Journal of Chemical Education}. 9: 1577; September 1932.
\textsuperscript{2}NEWELL, \textit{op. cit.}, p. 680.
\textsuperscript{3}HEPBURN, \textit{op. cit.}, p. 1582.
\textsuperscript{4}NEWELL, \textit{op. cit.}, p. 681.
\end{quote}
for several years the only American textbook in chemistry. "He wrote
books ... delivered speeches and was a sort of political and scientific
dictator."1

Fay2 related that a Samuel L. Mitchell, M.D. was appointed to Kings
(Columbia) College in 1792. "Mitchell claimed that he adopted the anti-
phlogistic system and that he taught the reformed chemistry of the French
and unfurled the banner of Lavoisier—sooner than any other professor in
the United States."

References to the contested theories of burning are particularly
interesting. It prefaces the arrival of Priestley in the United States.
Priestley, with his belief in the phlogiston theory of burning, came to
Northumberland, Pennsylvania from England in 1794. Theology was
Priestley's vocation and his views of religious and political freedom
were unpopular in England3. With chemistry as a demanding hobby, he had
become famous in the chemistry of gases. He is especially remembered as
the inventor of carbonated water. Benjamin Franklin, with Benjamin
Rush's recommendation, tried to get Priestley to take a teaching position
in chemistry at the University of Pennsylvania. Priestley not only
decayed that offer, but also declined one at the University of Virginia
which Thomas Jefferson was planning at the time. Priestley stayed in
Northumberland but trips to Philadelphia brought him in contact with

1NEWELL, op. cit., p. 681.
2FAY, PAUL J. "The History of Chemistry Teaching in American High
Schools." Journal of Chemical Education. 8: 1533; August 1931.
future leaders in American chemistry, particularly Robert Hare and Benjamin Silliman.

When Rush found Priestley would not be available, he recommended James Woodhouse who became professor of chemistry in the Philadelphia Medical School, 1795. Newell¹ pointed out "It is not difficult to predict what would have happened to the progress of chemical education in America if Priestley had accepted his appointment. He would have taught the tottering theory of phlogiston and impeded the advance of the new chemistry of Lavoisier".

Woodhouse was a brilliant teacher and experimenter. He was a time­less promoter of the newer chemistry. His two most famous students were Robert Hare and Benjamin Silliman. Woodhouse's Young Chemist's Pocket Companion is, in all probability, the first published guide in experimentation for chemical students².

B. Nineteenth Century Chemical Education in the United States

The ponderous change from the old chemistry to the new chemistry took place during the 19th century. At the beginning of the century there were several factors that kindled a popular demand for science in general and chemistry in particular. Fay³ listed such factors as

¹NEWELL, op. cit., p. 684.
³FAY, op. cit., p. 1513.
"... demand for democratic education, the necessity for exploiting natural resources, practical outlook of pioneers..." But he admitted, "the schools still adhered to an outmoded and formal humanism".

Newell\(^1\) indicated that of "140 colleges and universities established before 1820, chemistry was authorized or introduced into about half..." Between 1821-1839, 25 more institutions added chemistry courses.

Fay\(^2\) suggested that early academies gave chemistry more of a boost during this period than the colleges did. One of the earliest of these academies was the American Literary, Scientific and Military Academy founded at Norwich, Vermont, in 1820. Of 153 academies in New York State between 1840 and 1849, 90 percent of these academies offered chemistry. Thirty years earlier there had been no New York academies offering chemistry, out of 21 studied. During the period prior to 1850 there is evidence that chemistry became more popular in girls' than in boys' academies.

Fay\(^3\) said, "New England high schools apparently had less diversified curricula than the academies". He reported that 9 percent of Ohio high school students were studying chemistry in 1860, 4 percent in 1870, 6 percent in 1880 and 1890, and 5 percent in 1900. During this period

\(^{1}\)Newell, op. cit., p. 678.
\(^{2}\)Fay, op. cit., p. 1538.
\(^{3}\)Ibid., p. 1540.
\(^{4}\)Ibid., p. 1541.
chemistry in high school was less popular than natural philosophy and botany.

In spite of what might be considered a relatively low percent of students actually taking chemistry Fay\(^1\) reported that a consistently high percent of high schools offered chemistry; in the North Central States, from 1860 to 1900, 65 to 90 percent of high schools offered chemistry.

Men who set the pattern of chemical education during the 19th century in the United States, seemingly, were led by Benjamin Silliman. He was a student of Dr. James Woodhouse at the University of Pennsylvania and lifelong friend of Dr. Robert Hare. These men worked together and were influenced by meetings with Priestley.

Hare was a successful experimenter and in that way helped Silliman have well-rounded chemical experiences. Silliman himself was a great promoter and salesman as well as an able teacher. Browne\(^2\) reported "I suppose nearly every member of the American Chemical Society can trace his chemical ancestry through this or that teacher back to Silliman and I like to think that something of the liberality, benevolence and optimism of this grand old teacher has descended ... to the present age".

Famous chemical educators who studied under Silliman include Amos

\(^1\)Tbid., p. 1541.

\(^2\)BROWNE, C. A. "History of Chemical Education in America Between the Years of 1820 and 1870." *Journal of Chemical Education.* 9: 696; April 1932.
Eaton (1776-1842), Chester Dewey (1781-1867), Edward Hitchcock (1793-1864), Charles Sheppard (1800-1886) and Oliver Hubbard (1809-1900).

Silliman started the American Journal of Science in 1818 which has continued publication to the present day. Hare contributed over 200 articles to this journal, "beginning in 1818 with the first issues and continuing for over 30 years"1.

Silliman's promotion of chemistry extended beyond the classroom and journal. According to Browne2:

In 1831, (Silliman) began to give public lectures upon chemistry and geology in various cities of the United States...so popular...continued actively for twenty years...He probably exercised a wider influence by these lectures than by his teaching at Yale...Silliman made use of interesting experiments and these, coupled with his natural enthusiasm, animation and spirited delivery, gave him a reputation as a popular lecturer such as no other American chemist has acquired.

There were other influences upon chemical education beside Silliman's during the 19th century. Of these influences, the most important was the Medical Schools. The conflict here was the cultural aim of the colleges versus the aim for specialization, held by the medical schools. Browne reported regarding the specialization, "Eliminate the work of America's early chemist-physicians and the remainder of the contributions to the advancement of our science becomes pitifully small"3.

The influence of Dr. Robert Hare (1781-1858) is outstanding in this regard. His experimenting at the Medical School of the University of

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1NEWELL, op. cit., p. 687.
2BROWNE, op. cit., p. 700.
3Ibid., p. 702.
Pennsylvania has caused Browne\(^1\) to call him

\[\ldots\] the greatest chemist among the early teachers of this period of whom a very complete biography has been written by Professor (Edgar Fahs) Smith. \[\ldots\] He prepared his lecture experiments with great care and upon a scale of magnitude hitherto not attempted in America. Hare invented many new forms of chemical apparatus both for research and demonstration. \[\ldots\]

Laboratory instruction began in the United States during the 19th century. Browne reported that Silliman himself stated the pre-laboratory sentiments, "Many times have I said to those who as novices have offered aid to me that they might come and see what we were doing, and I should much prefer that they do nothing; for then they would not hinder me and my trained assistants, nor derange nor break the apparatus"\(^2\). Browne\(^3\) further reported "A general widespread realization of the importance of laboratory instruction in the curricula of our American colleges did not come until after 1870". Private laboratories were used for training twenty years or so before they were common in schools. Benjamin Silliman, Jr. has been given credit for the first regular laboratory course in an American college. "In 1842 the younger Silliman, while assistant to his father at Yale, fitted up a small laboratory in which daily instruction was given in experimental and analytical chemistry."\(^4\) Fay\(^5\) reported that high schools began to add chemistry laboratories

\(^{1}\)Ibid., p. 706.
\(^{2}\)Ibid., p. 712.
\(^{3}\)Ibid., p. 713.
\(^{4}\)Ibid., p. 715.
\(^{5}\)FAI, op. cit., p. 1549.
in 1850 and that by 1880 the new method was used in a considerable number of schools. In 1880, 129 schools replied to a questionnaire as follows:

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<th>Cities over 7500</th>
<th>Localities less than 7500</th>
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<td>Elementary lab.</td>
<td>35.7%</td>
<td>19.6%</td>
</tr>
<tr>
<td>Demonstrations</td>
<td>57.1%</td>
<td>56.1%</td>
</tr>
<tr>
<td>Textbook work</td>
<td>7.0%</td>
<td>24.3%</td>
</tr>
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Chemistry was the first United States high school subject to make much use of the laboratory method. It was evidently encouraged by university professors, especially some who had studied under the German professor, Baron Justus von Liebig.

Browne reported the shift to German chemical education.

Previous to 1840 in the eventful days of Dumas, Gay-Lussac, Thenard, Pelouze and other noted French chemists, the trend of American chemistry students who went abroad for postgraduate study was usually toward Paris. But after 1840, following the publication of Liebig's epoch-making volume, 'Chemistry in its Applications to Agriculture and Physiology' the tide of American chemistry students turned more from Paris to Giessen. Many American students returned to the United States from Giessen and advocated the laboratory method.

The 19th century saw textbooks run the gamut. The few existing textbooks at the opening of the century were of the lusty practical cookbook type. Chemistry textbooks at the close of the century were characterized by the academic reports of two very important committees.

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1Ibid.

2BROWNE, op. cit., p. 718.
of the National Education Association—the Committee of Ten and the Committee on College Entrance Requirements.

Both committees accepted the disciplinary aim of secondary education and took it as the point of departure. Both advocated courses of study in chemistry that were essentially college preparatory courses...Both committees emphasized in chemistry teaching the importance of a logical organization and of the experimental method. The standardizing influences of these reports was incautable.¹

Thus did chemistry textbooks as well as chemical education in the United States swing from very limited but practical information to more complete, disciplinary, logically-organized, college-preparatory type information. All these changes occurred in the 19th century.

C. Twentieth Century Chemical Education in the United States

Since 1900 psychologists have rejected the idea that "disciplining the mind" is an adequate aim of chemical education - or any other kind of education. Other dissatisfactions with chemical education at the turn of the century are voiced by Fay.²

Although college domination of high school chemistry has continued in many schools until the present time, a reaction began to take place during the first and second decades of this century. This included to varying degrees reaction against college domination, against too much uniformity and standardization, against the lack of vital relationship between chemistry instruction and every-day life, against the dominance of the laboratory, against the over-emphasis of mathematics, against the disciplinary aim of education, against the logical organization (rather than psychological organization) of the subject matter,

¹Fay, op. cit., p. 1552.
²Ibid., p. 1552.
and against an avid and uninteresting presentation of it. Pupils were rebelling against the dry bones set before them.

The foregoing reactions have evidently resulted in certain trends in chemical education. In 1939 Hall\(^1\) studied the trends by means of journal articles, college catalogs and questionnaires. The following trends were emphasized:

1. A trend to apply the methods of educational research to the organization of high school chemistry.

2. Trend away from the inclination to include more material toward the search for chemistry material valuable to all students.

The problems of what and how much chemistry should be in general education have been summarized by Dains\(^2\):

1. The bulk of the instruction (in chemistry) has been designed for the major in chemistry where the sequences have been developed by years of trial and experience and is on the whole fairly satisfactory.

2. On the other hand there is a growing feeling that ... (other students) ... should be given a general viewpoint of chemistry and its importance to the world in which he lives. We all agree that somewhere in high school or college everyone should have his exposure.

---


But electing the first four or five hours of a sequence
does not satisfy this need . . .

3. How best to handle a third class the members of which
are looking forward to medicine or biological fields
has become an increasing problem.

Fay\textsuperscript{1} reported high school textbooks were being written that attempted
to find a compromise between college preparation and general education:

The plan of including two sections in the textbook — the
first containing the topics essential to a basic understanding
of the science of chemistry and the second containing topics
of more direct utility — seems to be becoming the most common
plan adopted by progressive authors.

Howard\textsuperscript{2}, a scientist and Director, Division of Chemistry and Sanitation, New Hampshire Board of Health, took the following point of view
about chemistry in general education:

My personal feeling is that for the lay student, whether
he be in high school or in college, the teaching of chemistry
tends to be overdone in the sense that there is too much com-
plex theory, too much of the mathematical and physical phase,
too much of various things the knowledge of which will be of
no possible value to the future farmer, artisan, business man,
or housewife, and which knowledge will quickly fade. The
trouble, as I see it, is that some chemistry teachers are so
imbued with their subject that they are unconsciously bending
their efforts to the making of pseudo chemists of those who
will spend their lives in the ordinary every-day pursuits by
which most people gain a livelihood.

Ashford\textsuperscript{3} presented the following ideas based on a survey of 212

\textsuperscript{1}Fay, op. cit., p. 1555.

\textsuperscript{2}Howard, C. D. "Chemists and the Teaching of Chemistry." \textit{Journal of Chemical Education}. 20: 83; February 1943.

\textsuperscript{3}Ashford, T. A. "The Problem of Chemistry in General Education." \textit{Journal of Chemical Education}. 19: 262; June 1942.
At present, instruction for general education is cared for in three ways:

1. The traditional chemistry course which is designed primarily for the specialist.
2. Special chemistry courses which have been specifically designed for the nonspecialist.
3. Survey courses which consist of material taken from chemistry and other sciences.

Problems of each of the foregoing methods:

1. In the traditional type the attention is largely centered on the problem of caring for the specialist and nonspecialist in the same course.
2. Lack of instructional material for general education courses.
3. Development of tests. It is well recognized that at present there are no completely satisfactory tests to measure such objectives as critical thinking or the scientific attitude.

McGrath¹ made suggestions for teaching science in general education.

1. Encourage critical thinking.
2. Show the student what science is like.
3. Teach basic principles well but in limited numbers i.e.,

select indispensible items carefully.

4. Show what scientific procedure is like.

5. Show what scientists are like.

6. Construct the course to promote transfer of learning.

Hopkins reported a revision of the original list of "Essentials for High School Teachers" presented by the Division of Chemical Education of the American Chemical Society. This list represents some attempts to encompass college preparation with the needs of general education.

1. To show the service of chemistry to the home, to health, to medicine, to agriculture and to industry.

2. To develop this service around certain minimum fundamental topics, and, in doing so, to see that these minimum requirements are so well taught that they may be built upon, if required, as a foundation in college.

3. To train the student in keen observation and exact reasoning and in the scientific attitude of mind.

4. To develop a careful correlation between recitation and experiment.

5. To encourage students to keep notebooks which shall be an accurate record of laboratory experience expressed in concise, clear English.

6. To build upon the earlier science courses and knit them together.

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7. To encourage students to use reference books and scientific periodicals in addition to their textbooks.

8. To help pupils to find themselves i.e., to discover whether or not they have an aptitude for further study in chemistry or applied science, and, if so, to encourage such students to continue their study of science in university or technical school.

9. To stress the general principles involved in the specific cases studied.

10. To use well-established principles of psychology as far as they can be applied to students of high school chemistry.

Rowe summarized a study of junior colleges in California:

The junior college finds more demand for chemistry for the student seeking a general education and in this field chemistry teachers express themselves as being dissatisfied with the accomplishment so far. New ideas are constantly being given a trial. In the development of chemistry courses to meet special or sub-professional needs, the greatest progress has been in the fields for nurses and for laboratory technicians.

The supply of science students in the United States is not keeping up with the demand. At first experts of manpower thought the colleges were at fault but editorials in many newspapers and magazines now indicate the loss of science students is occurring at the secondary level.

The percent of high school students taking chemistry has never been

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1 Rowe, R. D. "Chemical Education in Junior Colleges." Journal of Chemical Education. 25: 373; July 1948.
high. Noll\textsuperscript{1} furnished information about the percent of students enrolled in public and private high schools of the United States who took chemistry: 1900, 8 percent; 1910, 7.1 percent; 1922, 7.6 percent; 1928, 7.3 percent. Noll believed part of the reason for the small percentages was that chemistry was not offered in many small high schools. A survey he noted in Nebraska listed such items as "too expensive", "no call for it", "not equipped for it", and "teaching staff to small" as explaining why chemistry was not offered.

It should be pointed out that in the Noll reported percentages, the denominator was the total number of high school students. Traditionally, high school chemistry has been a single year course. The percentages quoted take on more meaning if they are multiplied by four, or even more since the holding power of the high school has been less than 100 percent, particularly during the earlier part of the twentieth century.

Recent aids in the teaching of chemistry noted now but not noted in 1900 include the use of chemistry clubs, visits in industry, project methods, special reports, visiting speakers, radio, TV and drama. There has also been, in some cases, an effort to humanize the subject by the use of historical and biographical material. These newer methods have not been utilized in all classes. One of the characteristics of 20th century chemical education is increased diversification of content and methods. There is evidence that many classes in chemistry are conducted definitely on the 1900 basis. In others there has been concerted effort

\textsuperscript{1}Noll, V. H. "The Extent of Chemical Education." \textit{Journal of Chemical Education}. 12: 475; October 1935.
to adapt the chemistry course in a given high school to the needs of the particular community and, theoretically, even to the needs of the individual pupil.

Regarding a study of schools in Iowa, Worstell\(^1\) concluded "getting more students interested in the course (chemistry) is one of our biggest tasks. We can not sit back and be indifferent expecting the students to roll in because they will not!"

Ashford\(^2\) was concerned about teachers required for the chemistry students in the United States.

A serious problem is the matter of personnel. One difficulty is that of finding competent chemists who at the same time have a sufficiently broad background and sufficiently broad interests to understand the problems and devise methods of solving them.

A second difficulty is in keeping these people after they have been found. For if the emphasis on "pure research" for promotion is continued, few people of ability would continue to devote their energies to a purpose for which no recognition in terms of advancement is made, however strongly they might feel that such work is important to society.

Lewis\(^3\) reported returns on questionnaire from 50 colleges and universities that prepared 90 percent of the Ph.D.'s in science. Two-thirds of the science teachers said there has been a deterioration of instruction especially at the undergraduate level. Reasons given for the inadequate number of good teachers included (a) economic pressure—migration to

\(^1\)WORSTELL, R. A. "Chemical Education in Iowa High Schools." *Journal of Chemical Education*. 6: 1503; September 1929.

\(^2\)ASHFORD, op. cit., p. 262.

industry (b) administrative duties of chemistry teachers necessarily undertaken in order to secure promotions.

Fay believed that "the laboratory has been retained; but, just as the recent content of the course has tended to approach the informational and practical science of the middle of the nineteenth century, so the lecture demonstration has also tended to increase in popularity." An analysis of other literature indicates the correct ratio of laboratory work to lecture demonstration is still being sought.

It may be too early to select the giants in United States chemical education for the 20th century. The A. N. Marquis Company's standard American selective biographical reference Who Knows — and What lists six science educators but none of them is in the field of chemistry.

The foregoing information, about chemical educational in the twentieth century, has shown the need for education research regarding the following problems:

1. What is the relation of high school chemistry to college chemistry?

2. What is the place of chemistry in general education?

3. What should be done about students who know certain facts but do not understand the fundamental aspects of the scientific method?

4. What should be done about the critical loss of science talent at the secondary-school level?

1FAY, op. cit., p. 1555.
5. With seemingly more acute economic pressure in the United States, who will teach chemistry to the youth of the country?

The foregoing educational problems are acute in a democratic society. Opinions of desirability, as interpreted from a subjective analysis of published materials, reveal many opposing points of view. The large number of citations indicates clearly the importance of these problems in chemical education.

D. Historical and Biographical Material in the Teaching of Chemistry

Ideas about the use of biographical sketches in chemistry classes are in the current literature. This is true, partly, because of the relation of biographical to historical materials in science classes. Present day interest in science courses for general education has sent certain educators searching for a historical background in science. The thought has been that some form of historical presentation could help students, science majors or not, gain the science understanding needed even by laymen, in today's world. Extensive work by James B. Conant and collaborators at Harvard University has lent prestige to the historical approach. Evaluations of the use of history and biography in science classes have, for the most part, been subjective.

As early as 1925 Smith\(^1\), of the University of Pennsylvania, became concerned because he had received the doctorate in chemistry without any

\(^1\text{SMITH, EDGAR F. "Observations on Teaching the History of Chemistry." Journal of Chemical Education. 2: 533-555; July 1925.}
reference to the history of chemistry, either on his part or on the part of his examiners. As he searched for historical information to put into his own chemistry courses he discovered it was hard to locate. He assembled enough, however, for what he thought would be a few good lectures and as it turned out, "... (students) received the lectures with respect and some interest: but little enthusiasm was kindled, ... the old (lectures) evidently had been too exhaustive -- dry as dust -- devoid of the personal, human element --\(^1\)

So he went back to the sources and added anecdotal information about the people referred to his chemical lectures. He reported greater success:

The importance of the personal element was overpowering and could not be dismissed... it was believed that in presenting Frederick Wohler, for example, everything concerning the boy life, the student life, and the professional life of that eminent investigator should be woven in with his experimental contributions. ... It demanded wide, discursive reading; but eventually there was drawn such a picture of Wohler and his work that its reaction was quickly noticeable in the attitude of the students hearing the story. They behaved as if reviewing the achievements of one who was for the moment in their presence\(^2\).

According to Smith's experience, collections are a help in teaching history of chemistry. Through the years his office was filled with (a) photographs or prints, (b) autographed letters and (c) old chemistries associated with the men reported in his historical lectures.

\(^1\)Ibid., p. 534.

\(^2\)Ibid., p. 534.
A short time later Newell, at Boston University, reported methods of teaching the history of chemistry that he had found most useful:

During the twenty-five years in which I have taught the history of chemistry, certain facts which must be recognized in conducting a course in this subject have become evident. For example, students have little or no time, or possibly take little or no time, to read in a field which is broad or unfamiliar. General assignments usually result in general neglect. Hence, any course to be successful must have specific aspects. I discovered long ago that students are interested in chemists and will read about famous men. I discovered incidentally that they remember important discoveries made by famous men, particularly if the chemist and his discoveries are definitely connected. I found also that most of the students are willing to write papers, if the subject-matter is not too difficult to obtain and the subject itself is sufficiently inviting. On the basis of these observations, accentuated no doubt, to some extent, by my own interests, I developed a course about ten years ago and have tested it definitely with large classes during the last seven years.

No evidence of objective findings was observed in this article. On a subjective basis, though, Newell agreed with Smith in regard to the usefulness of collections for teaching history of chemistry:

Another observation made early in the course was the necessity of exhibiting considerable illustrative material. Hence, at each lecture as far as possible, I show portraits, autograph letters, books and sometimes lantern slides. I regard this as a vital part of the work. Students have repeatedly told me of their pleasure and profit derived from this material. Unless the portraits are expensive, I pass them about; even the autograph letters, protected by a celluloid cover, are passed about. The books are kept on the lecture table. Lantern slides are used infrequently, though in the last three years the size of the class has necessitated this method of presentation to considerable extent.

NEWELL, LYMAN C. "A Tested Method of Teaching the History of Chemistry." Journal of Chemical Education. 3: 166-169; February 1926.

Tbid., p. 167.
By 1930 a high school teacher from South High School, Denver, Colorado expressed ideas about the need for making early courses in chemistry more interesting to pupils. His work did not provide a turning point in chemical education or anything like that but the following quotation does state a grass-roots example of a problem that has been given considerable attention, in recent years, by chemical educators.

Last year from a graduating class of 236, 158 seniors had pursued the course of chemistry. Of this number approximately 100 have gone on to college. In college not more than twenty-five are taking chemistry, and of that number not more than three will ever make chemistry their life work. In other words, not over 1 percent of a high school graduating class will ever develop into professional chemists. With these facts facing us, I believe that chemistry must be taught for the 99 others who will never come into direct contact with chemistry again. Further, it must be taught in such a way as to awaken interest, instill love and encourage a student to continue his interest in the subject in later life, rather than cause a hatred of chemistry in the mind of the youth of today, which will persist in the man of tomorrow.

Another high school teacher, Sammis, stated that biographical material has interest value in chemistry classes:

History instructors and historians have long realized that pupils and readers are more readily attracted to the subject of history when it is taught or presented as a more or less connected series of biographies of the historically great than when offered as a pageant of events and their causes. Popularizers of science have also realized the interest-catching value of biographical

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1 COLLIER, ROBERT JR. "Methods of Increasing Interest in High School Chemistry." Journal of Chemical Education. 7: 2141-2149; September 1930.

2 Ibid., p. 2141.

material and have made extensive use of the lives of such scientific giants as Pasteur, Priestley, and Lavoisier and some of the more recent names such as Steinmetz and Einstein. The writers of chemistry texts have sensed this need for a historical background and now practically all elementary chemistry texts have a certain amount of material and pictures concerning the scientific leaders in the various branches of the science taken up in the book. ¹

With all this evidence to show the need and demand for historical and biographical information, are the science students in secondary schools and even freshman college and university courses getting any noticeable quality of such instruction? We think not. The author can remember several courses in chemistry and physics where all material relating to the lives of the men responsible for the work being studied was omitted, in some instances even ignored; there was not time for that sort of thing "with all the technical treatises yet to be covered."²

Sammis did, however, explain methods of presenting biographies he used in his own classes. A summary of these methods would include:

(a) five minute talks on the lives of great chemists, (b) talks given by students, (c) an average of two talks per week for about four months, (d) other pupils take notes during the reports, (e) subjects for talks chosen from a list of about 35 eminent scientists, (f) to a limited degree followed both chronological order and textbook order.

Regarding the results of using biographical information in his chemistry classes, Sammis wrote, "We who are presenting this work feel that we have been justified and amply rewarded in our efforts. The enthusiasm for such work was far in excess of what we originally anticipated, . . .³ He further suggested ideas about scientific attitude

¹ Ibid., p. 900.  
² Ibid., p. 900.  
³ Ibid., p. 902.
and method:

For those pupils who do not plan to go on in scientific pursuits, probably the most valuable thing to be gained from a course in science is an understanding and appreciation of the scientific attitude and method. A study of the lives of scientists, sketchy though it be, surely must help fix in the minds of young students the desirability of following scientific methods and an admiration for that quality in men which makes them overcome great obstacles, withstand personal hardships, ignore social prestige, and sometimes for sake wealth in the persistence of their search for the truth.1

By 1932 the Journal of Chemical Education2 had given a stamp of approval to the use of more history in the teaching of elementary chemistry:

We have previously discussed in these columns the virtue of the historical method of approach in the teaching of elementary chemistry from the standpoint of its potentialities as a humanizing and interest-promoting factor — in other words, as an aid toward the teaching of chemistry itself. We believe, however, that one may well give some consideration to the question whether the history of science in general has not a considerable primary value in its own right aside from its secondary value as an aid in making scientific subject matter more palatable.3

The inspirational value of biographies of eminent chemists was suggested as follows:

At an age when hero-worship is a natural trait there are held up for his admiration chiefly men who have stirred up a great deal of sound and fury signifying nothing. If these are to be his "great men", his heroes, can we wonder at it if his personal ambitions are trivial or worse? ... Insofar as his capacities permit he will pattern himself after the things and persons that he admires. It is true

1 Ibid., p. 902.

2 EDITOR'S OUTLOOK. "The Historical Approach." Journal of Chemical Education. 9: 1139; July 1932.

3 Ibid., p. 1139.
that we cannot make him admire significant figures merely by telling him about them, but it is equally true that he is not likely to admire men that he has never heard of or qualities which he cannot associate with actual human beings.¹

There was also the reference to scientific method:

As regards the effort to transmit some knowledge and appreciation of the scientific method to students, the fruitfulness of the historical approach is again evident. It is desirable that the student receive the impression that science is essentially "organized common sense". From this standpoint it is much more important that he be shown how conclusions are reached on the basis of experimental evidence than that he memorize the conclusions . . .

Too much emphasis has been laid upon the "hunch" or "revelation" in popular literature. Such phenomena are superficially spectacular and consequently dear to the journalistic heart. However, they tend to give students and other credulous people a badly distorted impression of the true nature of creative mental activity.²

The use of historical and biographical material in chemistry classes was popular enough by 1935 that Frank and Lunsted³, wrote:

Most teachers of general chemistry make frequent references to the men who have made the most important contributions to chemical knowledge and many teachers believe that the "historical approach" is most valuable in gaining the interest of the students. During the past ten years more than 350 historical and biographical articles have appeared in only two periodicals dealing with the teaching of chemistry.

It seems to be almost universally agreed that some understanding of the development of chemical theory and some knowledge of the work of men who have made important

¹Ibid., p. 1.
²Ibid., p. 1.
Contributions to chemistry is essential to an appreciation of the present-day status of the science and fundamental to any real education in this field. It seems to be agreed, also, that some knowledge of the pre-history of chemistry and its development out of the pseudo-science of alchemy is essential to a clear appreciation of its promise of future contributions to the progress of civilization.¹

In order to find the amount of agreement among textbook writers regarding what historical materials should be in chemistry texts, Frank and Lunstead studied 20 chemistry texts in common use at that time (1935). They were disappointed in their hope that, "... a summary of these data would yield generalizations which would be useful to teachers who wished to present chemistry in a more interesting and effective way." They summarized the disagreement among textbook writers as follows:

In spite of the widespread belief, among chemistry teachers, in the value of historical material as an aid in developing interest in chemistry and an understanding of its present status, there is no agreement among the textbook authors as to what historical material should be given nor as to how it should be presented.

General confidence is shown in cuts and mere mention of names, but few texts now available make anything more than a feeble and superficial attempt to present even the most meager outline of chemical history. No text presents a chronological account of the principal events in the development of chemical theory. It seems probable that in the quite obvious attempt of some authors of high-school texts to include an account of all new discoveries and developments and to make their texts deal with all known fields of chemistry, these authors are missing a fine opportunity to express the real spirit of chemistry, to dramatize the altruistic spirit of science for youthful minds, and thus to render most valuable contributions to the progress of truth.²

¹Ibid., p. 367.
²Ibid., p. 369.
About a year later, Oppe presented the following objectives for a unit of historical chemistry in a high school chemistry course:

1. To develop a knowledge of the past and an appreciation of these early attempts at scientific thinking.

2. To acquaint boys and girls with the men and women who have influenced the field of science from its beginning to the extent that they may become increasingly aware of the human side of chemistry, and develop a sympathetic attitude toward those who are engaged in the pursuit of science.

3. To show that out of the past has come a science which affects the present and offers to every citizen a method of treating intelligently problems which affect the welfare of our country and of all peoples.¹

Jaffe, chemistry teacher in the James Madison High School, Brooklyn, New York has been a strong advocate of history of chemistry in high school chemistry courses. In 1938 he suggested that conventional chemistry courses should be slightly modified to include more history:

Chemistry cannot, on the high-school level, be made solely the essence of a number of important biographies and researchers. The objectives of chemistry are too broad and the methodologies too varied to treat it merely as the biographies of its leaders. And neither do I recommend a course in the history of chemistry in the high schools.

But I do firmly believe that within the framework of a slightly modified course containing generally accepted minimum

¹OPPE, GRETA. "The Use of Chemical History in the High School. Journal of Chemical Education. 13: 412; September 1936.
essentials more historical material should be introduced. I believe that the history of chemistry should be made the leading thread in a beginning course. Facts are to be subordinated to intellectual appeals and to those other humanistic values which lie on the periphery of a course of study whose core continues to remain substantial enough to give it lasting strength. "Deep appreciations should go hand in hand with fundamental understanding." We must not fail to maintain a balance between the necessary factual material and the stimulating elements relating to the lives and accomplishments of the men and women who have given us a chemistry which can help the pupil to a clearer understanding of life and to a more healthful and complete one.\(^1\)

At this time he emphasized the use of the biographical method of presenting history:

One method is the biographical. "The great object, in trying to understand history, political, religious, literary or scientific, is to get behind the men and to grasp their ideas," wrote Lord Acton. It is the method of some of our best chemistry teachers like the late Edgar F. Smith and Charles Baskerville. Youth is a period of hero-worship, and there is high adventure in the life and struggle of many of the great figures of chemistry. From the lives of the chemists of the past and present can be brought out vividly and effectively many of the qualities of the true men of research. As a character builder it has few methods to equal it.\(^2\)

In outlining a greater shift to historical material for the future he recommended:

1. Courses in the history of chemistry and in the literature of science must be introduced in universities and teacher-training institutions and must be made an

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\(^1\) JAFFE, BERNARD. "The History of Chemistry and its Place in the Teaching of High-School Chemistry." Journal of Chemical Education. 15: 383-389; August 1938.

\(^2\) Ibid., p. 384.
essential requirement of all teachers of chemistry.

2. Curricula of chemistry must be rewritten or modified to include specific references to those elements of the historical background, the biographical and research narratives which should be taught. Excerpts from original researches should be printed in the course of study which the teacher is expected to follow.

3. Textbooks must be rewritten to include the material suggested above.

4. Other aids for developing the historical and cultural aspects of the science should also be employed, such as science club projects, scrap books, pictures of eminent chemists, and a series of films on the history of chemistry should be made available to beginners in chemistry.¹

It was well after World War II that an event occurred which gave rise to fresh thought and discussion concerning the historical approach to science teaching. Conant² was invited to deliver the twenty-third series of Terry Lectures at Yale University on the general topic of an historical approach to science. He wrote:

> Without this stimulation I should hardly have found either the time or the courage to formulate in a public document certain thoughts about teaching science which have been forming in my mind for many years.³

¹Ibid., p. 385.


³Ibid., p. XV.
When Conant stated the problem, it was, in a way, an expression of the problem regarding science in general education.

I propose to examine the question of how we can, in our colleges, give a better understanding of science to those of our graduates who are to be lawyers, writers, teachers, politicians, public servants, and businessmen.¹

For general education, Conant by-passed broad survey courses and recommended instead a series of case histories. These case histories were proposed to be relatively few in number to make a course in "The Tactics and Strategy of Science". He stated why he thought case histories should be selected from earlier rather than modern times:

The case histories would almost all be chosen from early days in the evaluation of the modern discipline. Certain aspects of physics in the seventeenth and eighteenth centuries; chemistry in the eighteenth and nineteenth; . . . The advantages of this method of approach are twofold: first, relatively little factual knowledge is required either as regards the science in question or other sciences, and relatively little mathematics; second, in the early days one sees in clearest light the necessary fumblings of even intellectual giants when they are also pioneers; . . .²

Conant set forth other principles he would use in selecting case histories for a hypothetical course:

I would wish to show the difficulties which attend each new push forward in the advance of science and the importance of new techniques; how they arise, are improved, and often revolutionize a field of inquiry. I should hope to illustrate the intricate interplay between experiment, or observation, and the development of new concepts and new generalizations; . . . But I should hope that almost all examples chosen would show the hazards which nature puts in the way of those who would

¹Ibid., p. 1.

²Ibid., p. 18.
examine the facts impartially and classify them accurately. The "controlled experiment" and the planned or controlled observation would be in the forefront of every discussion.1

Chemistry teachers who were interested in general education reacted favorably to ideas Conant expressed relative to history in science courses. Soon after the Terry Lectures were given, Wakeham stated:

It was left to President Conant to point out that an intelligent "understanding" of science might be most effectively achieved by developing the subject upon an historical basis.

Textbook writers are almost always mature scientists. They have mastered, organized and synthesized the subject matter into what seems to them to be a coherent, logical whole. They have probably long since forgotten the sequence of comprehensions through which they travelled in achieving a mastery of their special science... They are prone to unload upon the hapless freshman a formidable fraction of all they have accumulated in many years of concentrated effort. As the great majority of beginning chemistry students will never go on with the subject nor use chemical knowledge technically or professionally, it is a waste of their time to require them to absorb masses of chemical details for subsequent regurgitation in examinations. It is far more suitable to their needs to lead them into an "understanding" of the science. President Conant suggests that this can be achieved by the skillful presentation of carefully chosen topics, set in their historical and philosophical background. Most students enjoy a well-told tale and get the meaning of a scientific law or theory more easily from an apposite illustration than they do from an impeccably logical definition.2

After quoting from Conant's work, Strong3 defended teaching science

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1Ibid., p. 18.
2WAKEHAM, GLEN. The Use of History in Teaching Chemistry. Journal of Chemical Education. 24: 246; May 1947.
by way of its history from the standpoint of (a) effectiveness he asserted students will more readily grasp results achieved in a science if there is knowledge of questions that prompted the investigation, (b) appreciation (student learns not only the hypotheses that survived but also those which proved false and were discarded). Strong's final defense concerned:

... the existence of problems directly affecting the pursuit of science, problems which cannot be met without historical knowledge. I suppose, in short, the men concerned with work in a science are, or should be, also concerned with the conditions under which scientific work is furthered or obstructed. I would not question that the practical requirements in the immediate foreground are those of instruction in science or suppose that history of science could be a substitution.

What I do question is the notion that the historical study can be omitted without serious practical consequences.¹

Nash² agreed ... "there is ample room for improvement in public understanding of science ... in a country that spends more on its astrology than on its astronomy."³ He was looking for some "non-traditional" approach to the problem. After references to Conant's work he summarized:

To be sure, it is easier to construct an arbitrary imaginary account of a scientific development, that will well illustrate the points that are to be stressed, than it is to dig into the raw material of scientific history to disentangle the shifting threads of fact and fancy that

¹Ibid., p. 251.
²NASH, LEONARD K. A Historical Approach to the Teaching of Science." Journal of Chemical Education. 28: 146-151; March 1951.
³Ibid., p. 146.
made that history what it was. However, a start in the his­
torical research has already been made, for example in the 
new series of Harvard Case Histories in the experimental 
sciences which if it is supported, will undoubtedly be ex­
tended to cover a larger part of our great heritage of 
scientific history. The history of chemistry, in particular, 
presents an almost inexhaustible series of profoundly 
interesting and important developments, developments 
associated with the names of Berzelius, Kekule, Mendeleev 
and Arrhenius, to mention but a few. To date this his­
torical material has been largely ignored, yet it appears 
that one of the brightest hopes for successful teaching of 
science in general (and chemistry in particular) to non­
major students lies in at least a modest exploitation of 
this rich source of pedagogically valuable material.¹

Albrecht-Carrie² carefully reviewed Conant's work regarding un­
derstanding science by the historical approach. He agreed that, "In view 
of some of the basic difficulties, inherent in the nature of science 
itself this may perhaps be the best that can be hoped for."³ However, 
he issued the following warning:

It is well to be clear, however, that such an under­
taking is not the same thing as the history of science. 
Nor does Conant claim that it is, being concerned pri­
marily with filling the scientific gap, in the sense of 
conveying an "understanding of the meaning" of science, 
in the broad scheme of modern education.⁴

In July 1950 the Harvard Summer School held a Workshop in science 
in General Education Papers presented at this meeting were organized and 
published by Cohen and Watson.⁵ Cohen himself presented a paper entitled

¹Tbid., p. 151.
²ALBRECHT-CARRIE, RENE. "Of Science, Its History, and the Teaching 
³Tbid., p. 16.
⁴Tbid., p. 17.
⁵COHEN, I. B., AND WATSON, F. G. General Education in Science. 
The History of Science and the Teaching of Science. In it he stated:

I believe that our function as teachers in General Education is to help our students to like science; to enable them to enjoy their science course fully as much if not more than their other courses; to give them an understanding of what science is, how scientists work, and what science can and cannot do; to show them the effects of science on society and of society on science.¹

Cohen also maintained history of science is useful to both scientists and nonscientists:

From the strict point of view of the practicing scientist, a case may be made that the history of science is not a primary essential at least, the history of science may be less essential than, say, mathematics. Yet I firmly believe that the history of science is useful to the scientist just as it is to the nonscientist. Historians of a generation ago were often shocked at the violence with which scientists rejected the history of their own subject as irrelevant; they could not understand how the members of any academic profession could fail to be intrigued by the study of their own cultural heritage. What these historians did not grasp was that scientists will welcome the history of science only when it has been demonstrated that this discipline can add to our understanding of science itself and thus help to pro-duce, in some sense, better scientists.²

Wells³ has emphasized the importance of teaching beyond the facts of science:

In evaluating the contributions of science and scientific training to the physical mental and moral maturation of secondary school students, we must bear in mind the fact that the great majority of those enrolled will not themselves become professional scientists. It is in the realm of social awareness that integrated science education exerts its greatest

¹Ibid., p. 73.
²Ibid., p. 79.
influence, for much of the life and work of the high school teacher will be spent in enlightening the "average" young people in his classes (the rank and file of parents, consumers, critics and voters of tomorrow) in terms of attitude, judgment and appreciation.¹

Throughout the literature concerned with the historical approach to teaching science, recurring references to the scientific attitude and/or scientific method have been noted. There is apparently increasing agreement that the scientific method is not something that can be simply defined or stated in a series of definite steps. This does not preclude some agreement on certain minimum essentials. Examples of older and newer concepts of the scientific method are needed for clarity.

Before 1900 Pearson² summarized as follows:

The scientific method is marked by the following features: (a) careful and accurate classification of facts and observations of their correlation and sequence; (b) the discovery of scientific laws by aid of the creative imagination (c) self-criticism and the final touchstone of equal validity for all normally constituted minds.³

Fifty years later, except for oversimplification, Conant⁴ agreed with about two thirds of the foregoing: "With (b) and (c) one can have little quarrel since all condensed statements of this type are necessarily incomplete, but from (a) I dissent entirely."⁵

¹Ibid., p. 31.
³Ibid., p. 37.
⁵Ibid., p. 43.
Continuing with regard to Pearson's work, Conant said,

If science were as simple as this very readable account would have us believe, why did it take so long a period of fumbling before scientists were clear on some very familiar matters?\(^1\)

Conant was evidently considering the delayed merging of the empirical work of skilled artisans with the thinking of learned men when he wrote:

As I interpret the history of science, the sudden burst of activity in the seventeenth century which contemporaries called the "new philosophy" or the "experimental philosophy" was the result of the union of three streams of thought and action. These may be designated as (1) speculative thinking (2) deductive reasoning (3) cut-and-try or empirical experimentation.\(^2\)

Conant later called the foregoing, "The three elements in modern science . . ."\(^3\) He did not completely reject conventional statements about the scientific method:

I have read statements about the scientific method which describe fairly accurately the activity of an experimental scientist on many occasions (but not all). They run about as follows: (1) a problem is recognized and an objective formulated; (2) all the relevant information is collected (many a hidden pitfall lies in the word "relevant!"); (3) a working hypothesis is formulated; (4) deductions from the hypothesis are drawn; (5) the deductions are tested by actual trial; (6) depending on the outcome, the working hypothesis is accepted, modified or discarded.\(^4\)

Further in his writing, Conant made it clear he did not consider the foregoing to be "all" there is to science and that as such he did

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\(^1\)Ibid., p. 43.

\(^2\)Ibid., p. 45.

\(^3\)Ibid., p. 49.

\(^4\)Ibid., p. 50.
not believe in "the scientific method". This point of view tends to summarize current writing on the subject.

Ihde\(^1\) has recently maintained that the scientific method can be taught and learned even without being defined. He wrote:

> Just what is scientific method? ... I must submit that I really don't know. It is something like trying to define democracy or truth. It is the sort of thing all of us ... work with but ... which we really do not understand ... .

How then, if we do not understand it, can we teach scientific method? The problem is not utterly hopeless for we can utilize two approaches which will make experience with the scientific method a part of the students development. Student experience with scientific method can best be gained: (1) by observing and manipulating nature (the laboratory approach), and (2) by examining the observations and manipulations of original investigation (the historical approach) ... .

The historical approach to science instruction is merely sound teaching since it enables the student to see knowledge of the subject revealed in the manner in which it unfolded before the eyes of the greatest investigators in the field ... (without the historical approach) we expect the student to by-pass those essentials that practicing chemists had to master before they could proceed ... .\(^2\)

Ihde was so convinced of advantages in the historical approach he has gathered a list of references for historical material. He stated, "Copies may be obtained by writing to me at the Chemistry Department (University of Wisconsin).\(^3\)

\(^1\)IHDE, AARON J. "Learning the Scientific Method Through the Historical Approach." School Science and Mathematics. 53: 637-643; November 1953.

\(^2\)Ibid., p. 639.

\(^3\)Ibid., p. 643.
Jaffe's recent writing has provided a summary of the case of the use of historical and biographical materials in high school chemistry classes. With over thirty years experience as a chemistry teacher he has maintained that by slighting historical and biographical information, "... we are missing an opportunity to produce more and better scientists and more well-rounded citizens."²

He began using biographical material to combat lack of interest in his high school chemistry classes. Success was reported as follows:

A rich background was what I needed and I set out to get it. Soon I was using biographical material and other historical sidelights as a motivation in the teaching of chemistry. I really warmed up to this new tool; my enthusiasm carried over. Young people enjoy a good story. They imbibed the more strictly factual information less painfully. I started out to overcome the lethargy of my classes, and as I pictured the development of chemistry as a product of human achievement I was thrust more and more into the role of a modest historian of chemistry.³

Jaffe reported his pupils received cultural values:

The historical approach has also subtle, inspirational overtones. Few of our high school boys and girls have had any real conception of the spirit of the men of science — the impelling sense of curiosity, the mighty guiding urge, and the all-consuming fire sustaining them during centuries of incessant labor.⁴

Considerable attention was given by Jaffe to effectiveness of the historical approach in teaching the methods of scientists:

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¹JAFFE, BERNARD. "Using the History of Chemistry in Our Teaching." Journal of Chemical Education. 32: 183-185; April 1955.
²Ibid., p. 183.
³Ibid., p. 183.
⁴Ibid., p. 184.
The use of the history of science in the teaching of high-school chemistry reached out even beyond its value for the sustaining of interest, motivation, and inspiration. As I dug deeper into the business of writing of the history of chemistry, I realized more and more that through this approach the more enduring goals of science teaching could be attained more successfully. I am certain that at the high-school level, at least, the most important objective of science instruction is to inculcate and spread more widely the habits of scientific thinking and acting. It is generally known that nearly all the facts and formulas of elementary chemistry disappear rather quickly. The scientist's method of approaching and solving problems has a better chance of being retained longer. An effective way to teach the methods of science is to show how our great scientists reached their goals and how their minds worked in the process. Chemistry is studded with examples of the spirit and methods of science and offers striking illustrations of all of them.¹

Jaffe finally included the argument that the use of historical and biographical material in high school chemistry classes could increase interest of pupils in the profession of teaching science:

A final reason for using the historical background in the teaching of chemistry is its value in the recruiting of science teachers, especially at this time when there is a very critical shortage of such teachers throughout the country. In a report issued late in 1953 by a distinguished group of science educators, 'Critical Years Ahead in Science Teaching', one of the suggestions listed is for high-school teachers to work deliberately to encourage pupils to consider science as a vocation. At present we are failing to make science in its broadest sense attractive to the high-school population, was one of the conclusions contained in last year's report of a committee of the Central Association of Science and Mathematics teachers . . . Many a young man or woman was started on this road through the inspiration of some chemistry teacher who was able to arouse his interest and enthusiasm through case histories and stories of the great pioneers of chemistry.²

¹Ibid., p. 184.
²Ibid., p. 185.
The review of literature from 1925 to 1955 has revealed subjective evidence that more history and biography should be used in chemistry classes. The study that follows has attempted to get objective answers to certain aspects of the question: what happens when class time is taken from the usual class time to present biographical sketches?
III. CONTROL AND EXPERIMENTAL CONDITIONS

This study has been conducted in Ames, Iowa. The city of Ames was platted in 1865 and incorporated in 1870. It is reported to be Iowa's fastest growing city. Iowa State College and the State Highway Commission are here located. The rapid growth of each has contributed, both directly and indirectly, to the rapid population growth of Ames.

Data from the federal census reports show that Ames increased in population by 84.5 percent from 1900 to 1950. The 1950 report listed the Ames population as 22,898; of which approximately 8,000 were resident students at Iowa State College. In 1955, with 9,167 resident students at I.S.C. the Ames population estimate was 26,917.

Ames has remained a residential and institutional city. The Negro and foreign (bilingual) population, for all practical purposes, was nonexistent. In 1955 approximately 6 square miles were included with the corporate limits. Nearly 30 percent of this area was state-owned property. Disregarding the college enrollment, an average of 3.5 persons lived in each of 5,083 residential units. Of these residential units 27.4 percent were less than 10 years old.

The residents of Ames, over the years, have been predominantly middle-class when appraised on the basis of economic level. Although no evidence is available for substantiation, it is probable that extreme departures from middle-class economic level, both high and low, are less in Ames than those generally prevailing in cities of the size of Ames.
A. Ames High School

Ames High School for many years has been operated on the 6-3-3 plan. The three year enrollment has averaged approximately 500 students during the 5 years preceding this study.

The mean number of graduates each year from Ames High School was 150 from 1950 to 1954 inclusive as shown in Table 1. The mean number of these graduates who had received credit in chemistry was 82.4. On an average then, 54.9 percent of the Ames High School graduates had received credit for a full year of high school chemistry during the 5-year period.

Evidence is difficult to obtain which will yield a valid comparison of the percentage of high school graduates who have received credit in chemistry between Ames High Schools and other high schools in the United States. The most pertinent study, perhaps, was one made by Brown1 based on a 10 percent sample of public high schools. He found:

1. Half of the high schools offered chemistry.
2. The enrollment in chemistry (472,700) was equal to 31.9 percent of the number of students in the 11th grade.
3. The number of students enrolled in chemistry has increased twenty fold in the last 60 years but the percentage has not increased.

The percentage enrolled in chemistry, 31.9 percent is not directly

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Table 1

Ames High School Graduates and Iowa State College Chemistry Grades

<table>
<thead>
<tr>
<th>Year</th>
<th>1950</th>
<th>1951</th>
<th>1952</th>
<th>1953</th>
<th>1954</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three year high school enrollment</td>
<td>149</td>
<td>157</td>
<td>195</td>
<td>507</td>
<td>530</td>
<td>487.6</td>
</tr>
<tr>
<td>Number of graduates</td>
<td>153</td>
<td>141</td>
<td>153</td>
<td>144</td>
<td>159</td>
<td>150.0</td>
</tr>
<tr>
<td>Graduates with high school chemistry</td>
<td>77</td>
<td>65</td>
<td>87</td>
<td>87</td>
<td>96</td>
<td>82.4</td>
</tr>
<tr>
<td>Percentage of graduates with one year of high school chemistry</td>
<td>50.3%</td>
<td>46.1%</td>
<td>56.9%</td>
<td>60.4%</td>
<td>60.4%</td>
<td>54.9%</td>
</tr>
<tr>
<td>Number of high school chemistry students in each class who later took chemistry 101 at I.S.C.</td>
<td>31</td>
<td>18</td>
<td>29</td>
<td>28</td>
<td>34</td>
<td>28.0</td>
</tr>
<tr>
<td>Percent of A.H.S. chemistry students who later took chemistry 101 at I.S.C.</td>
<td>40.0%</td>
<td>39.1%</td>
<td>38.4%</td>
<td>32.3%</td>
<td>35.5%</td>
<td>37.0%</td>
</tr>
<tr>
<td>Mean grade point of A.H.S. chemistry students in chemistry 101 at I.S.C.</td>
<td>2.65</td>
<td>2.94</td>
<td>2.72</td>
<td>2.64</td>
<td>3.03</td>
<td>2.80</td>
</tr>
</tbody>
</table>

Comparable to the 54.9 percent of Ames High School graduates who have credit for high school chemistry. An unknown number of 11th grade students have been included in the denominator in obtaining the national percentage who have had no opportunity to receive chemistry credit since one-half of the public high schools did not offer chemistry. It is not possible to multiply this national percentage by two since schools not offering
chemistry tend to be the smaller schools.

As a result of the Brown study, it is apparent that the percentage of 11th grade high school students enrolled in chemistry who have had the opportunity to enroll lies between 31.9 percent and 63.8 percent. It is evident that the chemistry enrollment at Ames High School has been more nearly typical of high schools that offered chemistry than would have been expected from some popular press articles that have indicated as few as one student in eleven enrolled in chemistry.

During the five year period from 1950 to 1954, Ames High School had a mean number of 487.6 students in the 10th, 11th, and 12th grades, as shown in Table 1. To have a number comparable to nationwide figures available from the United States Office of Education¹ it would be necessary to have a four year high school. An approximate number to use for comparison was 4/3 x 487.6 or 650.13. Using the adjusted mean annual Ames High School enrollment of 824, the percentage of the total enrollment taking chemistry was 12.7 percent. This percentage was higher than national figures. It should be considered, however, that these data included information from schools in which no chemistry was offered. The following information² was furnished with regard to chemistry:

²Ibid., p. 107.
<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1890</td>
<td>20,503</td>
<td>10.1</td>
</tr>
<tr>
<td>1900</td>
<td>40,084</td>
<td>7.7</td>
</tr>
<tr>
<td>1910</td>
<td>50,923</td>
<td>6.9</td>
</tr>
<tr>
<td>1915</td>
<td>86,031</td>
<td>7.4</td>
</tr>
<tr>
<td>1922</td>
<td>159,413</td>
<td>7.4</td>
</tr>
<tr>
<td>1928</td>
<td>204,694</td>
<td>7.1</td>
</tr>
<tr>
<td>1934</td>
<td>339,769</td>
<td>7.6</td>
</tr>
<tr>
<td>1949</td>
<td>412,401</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Among the students who took a full year of chemistry at Ames High School, approximately 37 percent also took Chemistry 101 at Iowa State College as shown in Table 1. These individuals received a mean grade point of 2.8 in Chemistry 101 on the basis of A = 4, B = 3, C = 2, D = 1 and F = 0. On the same basis, Hunter found, in the fall quarter of 1947 when 1252 students registered in Freshman chemistry at Iowa State College, that the male engineering students who had also taken chemistry in high school secured a mean grade in Iowa State College Chemistry 101 of 2.14.

A more meaningful comparison between the Ames High School students and the foregoing engineering students who have taken chemistry may be found by eliminating all students from Ames other than those registering in engineering. Of the 140 Ames High School chemistry students who took Chemistry 101 at Iowa State College, 59 were engineering students. The mean grade point average in chemistry for these 59 students was 2.81 or about two-thirds of a letter mark higher than it was for the 228 similar students reported by Hunter. With the 59 students the chemistry marks

were: 18 A's; 16 B's; 21 C's; and 4 D's.

From the information shown by Hunter\(^1\), a mean high school average of 2.97 was found, as contrasted to the 2.88 from the 59 Ames students. The mean total score on the ACE examination was 121.3 for the Hunter group and 121.1 for the Ames group. The similarity of these means yields little evidence to suggest that Ames High School students who have taken chemistry in Ames High School and in other high schools differ in student ability as indicated by these two aptitude variables.

A regression equation was developed from the Hunter\(^2\) information and was found to be

\[
Y = 0.8824X_1 + 0.0063X_2 - 1.2266
\]

where

\[
Y = \text{predicted 101 chemistry mark}
\]

\[
X_1 = \text{high school average}
\]

\[
X_2 = \text{ACE total score}
\]

A prediction was made for each of the 59 Ames students who entered engineering. The actual chemistry mark was greater than the prediction for 48 students and was smaller for the remaining 11 students. These discrepancies between actual marks and prediction marks on an average was 0.717, or almost three-fourths of a letter mark. A test of significance was made of this mean difference from zero and yielded a t-value of 7.39, significant far beyond the 1% level.

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\(^1\) HUNTER, Ibid., p. 31.

\(^2\) Ibid., p. 31.
No hypotheses are proposed which might suggest reasons for the Ames High School students' superiority in Chemistry 101 over that of other engineering students of approximately similar aptitude as indicated by ACE scores or high school averages.

The median IQ of high school seniors varies from community to community. The median IQ, also, varies from one grade level to another. Information in the manual of the California Short-Form Test of Mental Maturity is shown in Table 2. The median IQ increases, as expected, from grade level to grade level. The median IQ for 25,000 youth in the 12th grade was reported to be 105.

Table 2

<table>
<thead>
<tr>
<th>Population</th>
<th>Number of Cases for Base</th>
<th>Median IQ</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>100,000</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>Ninth grade</td>
<td>25,000</td>
<td>101.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Tenth grade</td>
<td>25,000</td>
<td>103.0</td>
<td>15.5</td>
</tr>
<tr>
<td>Eleventh grade</td>
<td>25,000</td>
<td>104.0</td>
<td>15.5</td>
</tr>
<tr>
<td>Twelfth grade</td>
<td>25,000</td>
<td>105.0</td>
<td>15.0</td>
</tr>
<tr>
<td>College Freshmen</td>
<td>15,000</td>
<td>110.0</td>
<td>14.0</td>
</tr>
<tr>
<td>College Sophomores</td>
<td>1,000</td>
<td>114.5</td>
<td>13.5</td>
</tr>
<tr>
<td>College graduates</td>
<td>2,000</td>
<td>125.0</td>
<td>12.0</td>
</tr>
</tbody>
</table>
The median IQ for Ames High School seniors was 110, as shown in Table 3. The IQ's varied from less than 75 to more than 140. Regardless of the discrepancy between the median IQ for Ames and the national norms, the distribution of IQ's for Ames, as shown in Table 3, was not radically atypical from high school seniors in general. Among Ames High School seniors the median IQ was 114 for students electing chemistry and 106 for those not electing chemistry.

Table 3


<table>
<thead>
<tr>
<th>Percentile</th>
<th>Twelfth Grade IQ Norms</th>
<th>All Ames High</th>
<th>With Chemistry</th>
<th>Without Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>134</td>
<td>128</td>
<td>130</td>
<td>122</td>
</tr>
<tr>
<td>90</td>
<td>125</td>
<td>124</td>
<td>126</td>
<td>119</td>
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<tr>
<td>80</td>
<td>120</td>
<td>120</td>
<td>123</td>
<td>113</td>
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<td>70</td>
<td>115</td>
<td>116</td>
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<td>60</td>
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<td>112</td>
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<td>50</td>
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<td>114</td>
<td>106</td>
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<td>40</td>
<td>100</td>
<td>107</td>
<td>110</td>
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<td>30</td>
<td>96</td>
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<td>108</td>
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<tr>
<td>20</td>
<td>91</td>
<td>101</td>
<td>105</td>
<td>97</td>
</tr>
<tr>
<td>10</td>
<td>85</td>
<td>96</td>
<td>101</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
<td>92</td>
<td>96</td>
<td>85</td>
</tr>
</tbody>
</table>
Scientific interest of the Ames High School seniors was measured by the Kuder Preference Record, Vocational, Form CH. These seniors differed very little from the populations used for obtaining the norms shown on the Kuder Profile Sheet.

For the measures taken prior to the high school chemistry course, the norms of Ames High School seniors were similar to the norms furnished by Kuder for boys and girls, as indicated by Tables 4 and 5. At each decile the agreement between the foregoing norms was very high. In both tables the norms of the pupils who elected chemistry tended to be higher and norms of the pupils who did not elect chemistry tended to be lower than the Kuder norms.

Information available from IQ's and scientific interests yield little evidence to indicate that generalizations drawn from Ames High School are not applicable to all high schools in the United States. Small differences in median values may or may not prevail. The important consideration from the standpoint of generalization is the similarity of Ames High School students to the general high school population receiving credit for high school chemistry. The overlapping in the distributions of IQ's, scientific interests and other student characteristics far overshadow slight differences in median values.

Until such a time when evidence suggests otherwise, inferences concerning the effectiveness of increased emphasis upon biographical sketches drawn from Ames High School are assumed to be reasonably valid for the population consisting of all high school students of chemistry in the United States.
### Table 4


<table>
<thead>
<tr>
<th>Kuder Percentile</th>
<th>Kuder Group</th>
<th>All Ames High</th>
<th>Chem</th>
<th>Non-Chem</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>62</td>
<td>60</td>
<td>62</td>
<td>52</td>
</tr>
<tr>
<td>90</td>
<td>57</td>
<td>57</td>
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<td>85</td>
<td>55</td>
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<td>75</td>
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<td>70</td>
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<tr>
<td>10</td>
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<td>23</td>
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<td>22</td>
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<tr>
<td>5</td>
<td>22</td>
<td>16</td>
<td>15</td>
<td>16</td>
</tr>
</tbody>
</table>

### B. Without Emphasis on Biographical Sketches

The 94 pupils enrolled in chemistry for the entire school year 1954-1955 at Ames High School provided the control group of this investigation. Each pupil in this group was assigned to one of the first four class periods in the school day of six periods as shown in Table 6. Each class period was scheduled 55 minutes in length which was sufficient.
Table 5
Scores on the Kuder Scientific Interest of Ames High

<table>
<thead>
<tr>
<th>Kuder Percentile</th>
<th>Kuder Group</th>
<th>All Ames High</th>
<th>Chem</th>
<th>Non-Chem</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>53</td>
<td>52</td>
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<td>15</td>
</tr>
<tr>
<td>25</td>
<td>21</td>
<td>18</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>19</td>
<td>16</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
<td>15</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>13</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>10</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

time to satisfy the North Central Association requirements for either recitation or for laboratory periods. Periods I, II and III were morning periods and Period IV the first one after lunch. All four classes met daily, 5 days per week through the regular school year.

During the school year 1954-1955 the investigator taught all the chemistry classes at Ames High School. The methods of instruction were
Table 6
Ames High School Chemistry Classes in the Control Group, 1954-1955

<table>
<thead>
<tr>
<th>Period</th>
<th>Meeting Time</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td>I</td>
<td>8:58 - 9:53</td>
<td>12</td>
</tr>
<tr>
<td>II</td>
<td>9:56 - 10:51</td>
<td>14</td>
</tr>
<tr>
<td>III</td>
<td>10:54 - 11:49</td>
<td>13</td>
</tr>
<tr>
<td>IV</td>
<td>1:00 - 1:55</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Percentage of Enrollment</td>
<td>55.3%</td>
<td>44.7%</td>
</tr>
</tbody>
</table>

those developed by several years of experience in science teaching. Included in the instruction were lectures, recitations, special reports, demonstrations, individual laboratory work, visual aids, an occasional visiting speaker and an occasional field trip.

All high school chemistry classes were held in Room 211 in the high school building. The facilities were conventional. Room 211 had tables and chairs in the front for class work and lockers with sinks, water and gas in the rear for laboratory work. A large demonstration table was on a platform, center-front. The only exhaust flue was a small, wall-type flue at the rear of the room. The administration furnished materials for class work as requested by the teacher.
The laboratory work was particularly flexible. With equipment available in the classroom and with each period long enough for a well-organized experiment, the laboratory work was done at the time it was most needed in the course.

Carefully selected 16 mm films were ordered a year in advance in an effort to have a certain film the day it would add most to the current unit. Although a special visual aids room was available, most 16 mm films were shown in Room 211. By advanced planning it was also possible to have strip film, slide and opaque projectors on the exact days required by the course.

The basic textbook\(^1\) was furnished for each high school chemistry student. It was a conventional high school chemistry textbook and to some extent, it contained information concerning the men who developed the science of chemistry. The chemistry course for the control group of this investigation did not emphasize the lives of famous chemists any more than would be expected from textbook content or from student classroom reaction.

Assignment sheets were available for each student for most of the units throughout the year. They were available for each of the first seven units. Since the first seven units were used to obtain the criterion for achievement in fundamentals of chemistry, a copy of the assignment sheets for the first seven units has been placed in the Appendix. Information not underlined on the assignment sheets was available to the control group in this investigation.

---

The 91 pupils enrolled in chemistry the first week of the school year 1955-1956 at Ames High School provided the students needed for the experimental group in this investigation. The four chemistry classes in the experimental group were similar in size to those of the control group shown in Tables 6 and 7. They met at the same hours of the day and for the same length of time. Both groups met in the same classroom, had the same equipment and materials available, used the same basic textbook and had the same teacher.

Table 7

Ames High School Chemistry Classes in the Experimental Group, 1955-1956

<table>
<thead>
<tr>
<th>Period</th>
<th>Meeting Time</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td>I</td>
<td>8:50 - 9:53</td>
<td>13</td>
</tr>
<tr>
<td>II</td>
<td>9:56 - 10:51</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>10:54 - 11:49</td>
<td>16</td>
</tr>
<tr>
<td>IV</td>
<td>1:00 - 1:55</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>61</td>
</tr>
</tbody>
</table>

Percentage of Enrollment

67% 33% 100%
There was, however, disproportionality with regard to sex. The control group was 55.3 percent boys and 44.7 percent girls whereas experimental group was 67.0 percent boys and 33.0 percent girls.

In every respect except one, the teacher attempted to keep the teaching methods the same for the control group and for the experimental group. The same amount of time for each of the first seven chemistry units was available for the experimental group as for the control group. The assignments for each regular class period are shown in the Appendix. The parts not underlined were assigned to both groups.

The teaching method that differed from the control group to the experimental group was with regard to the biographical sketches that were presented in the classes of the experimental group. The underlined parts of the copy of the assignment sheets, which were concerned with biographical sketches, were included in assignment sheets presented to the experimental group but not included in assignment sheets presented to the control group.

The first biographical sketch was presented to the experimental group by the teacher as a guide to students who would give other biographical sketches later. At the time of the teacher's presentation of the first biographical sketch, the students received copies of (1) instructions for the biography section of the chemistry notebook shown in the Appendix, (2) guide notes for the report on Aristotle which followed the foregoing instructions, (3) a bibliography of histories and biographies of chemists, shown in the Appendix, which included selected
references from a list furnished by Ihde\(^1\) and (2) a list of chemists, shown in the Appendix, from which each student was asked to select one subject for his own biographical sketch presentation.

The teacher and students discussed instructions for the presentation of biographical sketches. It was emphasized that the reporter should follow a plan which would enable class members to take notes according to the notebook instructions, as shown in the Appendix. It was further emphasized that notes from biographical sketches should be filed in chronological order, according to some important date from the scientist's biography. It was explained this procedure would help the student fix in mind the correct period of time in which the scientist made his contributions.

It was further emphasized by the discussion that although personal items in the scientist's life were difficult to obtain, they had been found to make striking contributions to biographical sketches.

The most subtle part of the outline for biographical sketches was section IV, "Problems the Scientist Faced and the Way He Solved Them." As reports were given later by students the tendency was to list handicaps under this section. It was necessary for the teacher to keep struggling with the idea that this section was for a statement of the science problems the scientist recognized, outlined or limited and then attempted to solve. The teacher usually found it necessary to summarize this section and to stress methods used by the scientist which appeared to lead to

success.

As a final part of the discussion regarding presentation of biographical sketches, plans were made for inspection of the biographical notebooks. A complete file of the biographical sketches was made a requirement of each student in the experimental group.

The review of related literature had revealed that most of the teachers who had tried historical and biographical material in chemistry classes recommended that collections, in connection with the reports, were highly motivating. The teacher of the classes in this investigation had no original manuscripts, books, glassware or other items connected with the scientific lives of the famous chemists. He did, however, arrange certain visual aids as a substitute. Using a reflex camera with auxiliary lenses he photographed pictures in books and other publications. By purchasing Kodochrome film, four 36-exposure rolls at a time, he was able to have 2 inch by 2 inch slides at a cost of approximately eleven cents each.

Slides were used with each of the biographical sketches. They were shown after the report and after a short discussion period. The slides stimulated a short review of the important items in the report. Students were apparently interested in slides that showed such things as the notes on atomic weights as photographed from Dalton's own notebook, the photograph of Faraday's laboratory, the handwriting, signatures and pictures of famous chemists.

Although students were asked to aim at 10 minute reports on their biographies, the time actually used was more than 10 minutes. Including time for an introduction, the report, question period and showing of
slides, the mean time required was 20 minutes per biographical sketch. This did not include time for making or discussing biography assignments nor for biographical notebook inspections.

The number of biographical sketches presented in each of the first seven chemistry units is shown in Table 8.

Table 8

<table>
<thead>
<tr>
<th>Emphasis Information</th>
<th>Unit Number</th>
<th>For All Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Number of Class Periods</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Class Time (Approx. in Minutes)</td>
<td>330</td>
<td>220</td>
</tr>
<tr>
<td>Number of Biographical Sketches</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Time Spent with Biographical Sketches (Approx. of Minutes)</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Percentage of Class Time Spent with Biographical Sketches</td>
<td>24.2</td>
<td>9.1</td>
</tr>
</tbody>
</table>
In all seven units a total of 16 biographical sketches were presented to the experimental group. In the experimental group, for the entire seven units, approximately 14 percent of the class time was used for biographical sketches. Periods used for the unit tests were not considered in determining the class time shown in Table 8. Class time for each of the seven units was the same for the experimental and the control groups. The same amount of time was used for testing the experimental group as was used for testing the control group.
IV. METHOD OF PROCEDURE

Information needed for this study was obtained from records available in the Ames High School and from data personally collected by the investigator.

From Ames High School data were assembled as follows: (1) the most recently recorded IQ, (2) grades for two semesters of plane geometry, (3) four standard scores from the Iowa Tests of Educational Development; one for background in natural sciences; one for ability to interpret readings in natural sciences; one for ability to do quantitative thinking; and a composite score, (4) the Kuder Preference Record score most recently available prior to the chemistry course. These data were obtained for their possible usefulness as control factors in testing the hypotheses included in this study.

The investigator personally collected the criterion scores for each of the six objectives chosen for this study. These objectives were:

- Fundamentals of high school chemistry
- Men and events in chemistry
- Scientific method
- Scientific attitude
- Scientific interest
- Science activities and ambitions

These objectives and their evaluation will be described individually in the sections which follow.

In the evaluation of the criteria, it is likely the usefulness of control factors may vary from one criterion to another. Preliminary investigation of the usefulness suggested that the geometry grade and the IQ be retained for control throughout this study. The choice of
these two variables was based largely upon correlations with the criteria, although the usual availability of such factors was also considered.

It appeared to be desirable to stratify on the basis of sex since with some of the criteria sex differences might be quite pronounced. If stratification is to be made by sex disproportionality can be seen to exist between the control group with 53 percent boys and the experimental group with 67 percent boys as shown in Table 9.

Table 9

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys Available Sample</th>
<th>Girls Available Sample</th>
<th>Both Available Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>61</td>
<td>30</td>
<td>91</td>
</tr>
<tr>
<td>Control</td>
<td>51</td>
<td>41</td>
<td>92</td>
</tr>
<tr>
<td>Total</td>
<td>112</td>
<td>71</td>
<td>183</td>
</tr>
</tbody>
</table>

Since the usual formulas for analysis of variance and of covariance demand proportionality it was necessary to choose a sample in which the percentage of boys and girls would be the same for the control and experimental groups. Since the major hypotheses to be tested were with regard to the control and experimental groups rather than on the basis of sex, a sample was needed which would furnish the largest number for
these two groups in which proportionality could be obtained. Thus the sample used in this study consisted of 50 boys and 30 girls in the control group and the same numbers in the experimental group, a total of 160 students. Students available but not needed in the sample were eliminated by the use of a table of random numbers.

The similarity between the control and experimental groups may be noted from the mean IQ's shown in Table 10. The experimental group excels on an average by 0.9 of an IQ point and the girls exceed the boys by 2.43 IQ points. A test of significance was made by an analysis of variance of the IQ's and is shown in Table 11. No significant differences were found.

Table 10
Mean IQ's of Experimental and Control Groups for Boys and Girls

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Experimental</td>
<td>114.26</td>
<td>115.87</td>
</tr>
<tr>
<td>Control</td>
<td>112.74</td>
<td>116.00</td>
</tr>
<tr>
<td>Total</td>
<td>113.50</td>
<td>115.93</td>
</tr>
</tbody>
</table>
Table 11
Analysis of Variance of IQ's for Experimental and Control Groups for Boys and Girls

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental-Control</td>
<td>1</td>
<td>32.40</td>
<td>32.40</td>
<td>0.54</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>222.04</td>
<td>222.04</td>
<td>1.42</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>25.63</td>
<td>25.63</td>
<td>0.48</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>17200.71</td>
<td>110.26</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>17480.78</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The control group and the experimental group were also similar with regard to achievement in geometry as shown in Table 12. The control group was superior by 0.5 grade points, or by 1/4 letter grade per semester. The girls excelled the boys by 0.38 grade points. The results of an analysis of variance with respect to geometry grades are shown in Table 13. Since none of the t-values was significant the similarity of the control and experimental groups was again demonstrated.

The analysis of covariance was the technique followed in testing the criteria in spite of the apparent similarity of the control and experimental groups. The use of this technique reduces the error term in the test of significance enough to make the test of significance more sensitive than would a disregard of the control factors in the analysis.
### Table 12

Mean Geometry Marks for Experimental and Control Groups for Boys and Girls

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys</th>
<th>Girls</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>5.18</td>
<td>5.57</td>
<td>5.26</td>
</tr>
<tr>
<td>Control</td>
<td>5.66</td>
<td>5.93</td>
<td>5.76</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5.37</td>
<td>5.75</td>
<td>5.51</td>
</tr>
</tbody>
</table>

### Table 13

Analysis of Variance of Geometry Marks for Experimental and Control Groups for Boys and Girls

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental-Control</td>
<td>1</td>
<td>10.000</td>
<td>10.000</td>
<td>1.85</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>5.115</td>
<td>5.115</td>
<td>1.36</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.427</td>
<td>0.427</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Within</strong></td>
<td>156</td>
<td>454.133</td>
<td>2.911</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>159</td>
<td>469.975</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
One important objective in high school chemistry is the degree to which a student acquires a knowledge of the fundamentals of high school chemistry. For purposes of this study, the criterion for this objective was limited to such achievement on the first seven units of the course, i.e., (1) matter, (2) oxygen, (3) hydrogen, (4) water, (5) atoms and formulas, (6) equations, and (7) atmosphere.

At the end of each unit an objective test was given to all students in the control and experimental groups. The test, with few exceptions, consisted of multiple-choice items. The sum of the scores on these seven units was divided by ten to yield a criterion score for each student. Theoretically, the scores could vary from a minimum of zero to a maximum of 90.4. With the 160 students included in this study, the scores varied from 42.3 to 88.4 with a mean of 71.4 and a standard deviation of 11.1.

The mean scores for boys and girls, with and without increased emphasis on biographical sketches, are shown in Table 11. In the sample of 160 students, the girls excelled the boys in achievement of the fundamentals of chemistry; students in the experimental group excelled those in the control group; and girls seemed to profit more than boys from the increased emphasis on biographical sketches.

The differences in means, shown in Table 11, may have resulted from variations such as are to be expected when random samples are drawn from a single population. A preliminary test of significance, disregarding known individual differences in student aptitude, was made from an
analysis of variance shown in Table 15.

**Table 14**

Mean Scores of Achievement in Fundamentals of Chemistry

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys</th>
<th>Girls</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>73.15</td>
<td>76.86</td>
<td>74.54</td>
</tr>
<tr>
<td>Control</td>
<td>67.92</td>
<td>68.87</td>
<td>68.28</td>
</tr>
<tr>
<td>Total</td>
<td>70.54</td>
<td>72.86</td>
<td>71.41</td>
</tr>
</tbody>
</table>

**Table 15**

Analysis of Variance of Achievement in Fundamentals of Chemistry

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental-Control</td>
<td>1</td>
<td>1569</td>
<td>1569</td>
<td>3.69**</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>203</td>
<td>203</td>
<td>1.33</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>72</td>
<td>72</td>
<td>0.79</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>17977</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>19821</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level.**
Evidence from this analysis failed to disprove the null hypothesis that sex differences do not exist and that boys and girls respond the same to the control and experimental treatment. Greater emphasis upon biographical sketches results, under conditions prevailing in this study, in increased achievement in the fundamentals of chemistry as evaluated. The foregoing inferences have been drawn without regard to known individual differences in student aptitude.

A more satisfactory test of significance may be obtained from an analysis of covariance in which some degree of control of student aptitude can be accomplished. The purpose of the analysis of covariance is two-fold, i.e., (1) to adjust the sums of squares for the main effects and the interaction for group differences in the means of the control variables and (2) to render tests of significance more sensitive. The former will be reflected in some changes in the magnitude of the sums of squares for the main effects and the interaction of the within sum of squares, the amount of the reduction being contingent upon the degree of relationship between the criterion and the battery of control variables.

An analysis of covariance was made so that tests of significance could be made with the use of a battery of two control variables, the IQ and the geometry mark. Students in the experimental group, receiving special emphasis on biographical sketches, had higher IQ's on an average, than did students in the control group, not receiving an increased emphasis on such sketches, the difference being 0.9 of an IQ point. Students in the control group, on the other hand, received higher marks in geometry, on an average, than did students in the experimental group, the difference being 0.5, or one-fourth of a letter mark for each semester.
The usual methodology of covariance analysis was followed. As a preliminary step, sums of squares and cross-products in deviation form were obtained from the original sums shown in the Appendix. These sums of squares and cross-products were classified by sources of variation into (1) control-experimental (2) sex, (3) interaction and (4) within subgroups.

Four series of values were needed for the solution of the normal equations. One series was based on the within subgroups sums of squares and cross-products. The other three were obtained by adding the sums of squares and cross-products for each of the main effects and interaction to those computed for within the subgroups.

These normal equations were solved simultaneously and the resulting equations in deviation form for predicting achievement in fundamentals of chemistry from IQ and geometry marks are shown in Table 16, together with the analysis of regression for each of the four sets of normal equations.

The usefulness of the control factors was indicated by a coefficient of multiple correlation of 0.788. The relative contributions of the IQ and geometry marks in the prediction of achievement in fundamentals of chemistry was 11 percent and 86 percent, respectively.

The analysis of covariance is shown in Table 17. There is a significant difference in achievement in the fundamentals of chemistry between control and experimental groups. Sex differences in such achievement between boys and girls could not be demonstrated. Evidence failed to indicate that either boys or girls profited more, or less, with increased emphasis upon biography sketchs, as indicated by the
### Table 16

**Analyses of Regression of Achievement in Fundamentals of Chemistry**

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression (^1)</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom for Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Regression</td>
</tr>
<tr>
<td>Within plus Control-Experimental</td>
<td>( y = 0.22971x_1 + 3.74027x_2 )</td>
<td>19546</td>
<td>10100</td>
</tr>
<tr>
<td>Within plus Sex</td>
<td>( y = 0.15867x_1 + 4.34679x_2 )</td>
<td>18180</td>
<td>11360</td>
</tr>
<tr>
<td>Within plus Interaction</td>
<td>( y = 0.15359x_1 + 4.34676x_2 )</td>
<td>18049</td>
<td>11390</td>
</tr>
<tr>
<td>Within Alone</td>
<td>( y = 0.15764x_1 + 4.34130x_2 )</td>
<td>17977</td>
<td>11160</td>
</tr>
</tbody>
</table>

\(^1\) \( y \) = deviation score for achievement in fundamentals of chemistry.

\( x_1 \) = deviation IQ.

\( x_2 \) = deviation geometry mark.
Table 17
Analysis of Covariance of Achievement in Fundamentals of Chemistry

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>2629</td>
<td>2629</td>
<td>7.70**</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0.26</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>42</td>
<td>42</td>
<td>0.96</td>
</tr>
<tr>
<td>Within</td>
<td>154</td>
<td>6817</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level.

The analysis of variance, shown in Table 15, and the analysis of covariance, shown in Table 17, indicate clearly the advantage of the latter, whenever control variables can be identified which correlate highly with a criterion. The within mean square for the former was reduced from 115 to 44 for the latter, thus reducing materially the denominator term used in a test of significance, tending to increase the t-values.

The control-experimental mean square was 1569 in the analysis of variance and 2629 in the analysis of covariance. If the two groups had identical mean IQ's and mean geometry marks, these two mean squares would be identical. The larger mean square was found in covariance,
indicating that, whichever group was superior without control, its superiority was increased by considering the IQ and geometry marks for each student.

The mean score for the experimental group was 74.5 and for the control group it was 68.28, as shown in Table 14. The difference between the means was 6.26. When the differences between the mean IQ's and between the mean geometry marks are substituted in the within regression equation the adjusted mean difference would be 2.03 greater. Thus, if the two groups had identical mean IQ's and mean geometry marks, students with increased emphasis on biographical sketches, on an average, would have excelled students in the control group by 8.29.

This adjusted mean difference represents three-fourths of a standard score unit. Thus, a student making normal progress who would be in the 50th percentile rank in the control group, would be in the 78th percentile rank in a group with increased emphasis upon biographical sketches.

It was not unexpected to find evidence in this study to substantiate the effectiveness of using biographical sketches in the teaching of high school chemistry. This point of view has been often expressed in science education periodicals. It was unexpected to find the magnitude of this effectiveness so great when evaluated in terms of achievement in the fundamentals of chemistry since class time spent with biographical sketches reduced the class time spent in other learning activities.
At least from a cultural point of view the degree to which a student acquires knowledge of men and events in chemistry is an acceptable objective in high school chemistry. For purposes of this study the criterion for the foregoing objective was limited to the score on a 53-item, multiple-choice test shown in the Appendix. Students in the control and experimental groups were informed before the test was given that the score on this test would be considered in arriving at a final mark for the course.

The test was given to all students in the control and experimental groups after pertinent material has been covered in the course. The same amount of time for the test was available to each group. Answers to all 53 items appeared in the course textbook a copy of which was in the hands of each student in both groups. The 53-item test was scored one point for each correct response and the 160 scores from the sample used in this study varied from 13 to 48 with a mean of 26.9 and a standard deviation of 7.5. The estimated coefficient of reliability was 0.77.

The mean scores for students, with and without increased emphasis on biographical sketches, are shown in Table 18. In the sample of 160 students, those in the experimental group excelled those in the control group by 6.66 in the achievement of men and events in chemistry. The girls profited more than the boys by the increased emphasis on biographical sketches. A preliminary test of significance, disregarding individual differences in student aptitude, was made from an analysis of variance shown in Table 19. The highly significant t-value for
Table 18
Mean Scores of Achievement in Men and Events in Chemistry

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td>29.16</td>
<td>32.07</td>
<td>30.25</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>24.34</td>
<td>22.33</td>
<td>23.59</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26.75</td>
<td>27.20</td>
<td>26.92</td>
<td></td>
</tr>
</tbody>
</table>

Table 19
Analysis of Variance of Achievement in Men and Events in Chemistry

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>1775.56</td>
<td>1775.56</td>
<td>6.31**</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>7.59</td>
<td>7.59</td>
<td>0.41</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>226.32</td>
<td>226.32</td>
<td>2.25*</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>6952.47</td>
<td>44.57</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>8961.94</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5% level.  ** Significant at 1% level.
control-experimental in Table 19 shows that greater emphasis upon biographical sketches results, under conditions present in this study, in increased achievement in men and events as evaluated. The t-value for interaction is significant at the 5% level and indicates boys and girls responded in a significantly different manner in the control and experimental groups. However, evidence from this analysis failed to disprove the null hypothesis that sex differences do not exist. The foregoing inferences were drawn without regard to known individual differences in student aptitude.

A more satisfactory test of significance may be obtained from an analysis of covariance in which some degree of control of student aptitude can be accomplished. The purpose of the analysis of covariance is two-fold, i.e., (1) to adjust the sums of squares for the main effects and the interaction for group differences in the means of the control variables and (2) to render tests of significance more sensitive. The former will be reflected in some changes in the magnitude of the sums of squares for the main effects and the interaction of the within sum of squares, the amount of the reduction being contingent upon the degree of relationship between the criterion and the battery of control variables.

An analysis of covariance was made so that tests of significance could be made with the simultaneous use of two control variables, the IQ and the geometry mark. Students in the experimental group, receiving special emphasis on biographical sketches, had higher IQ's on an average, than did students in the control group, not receiving an increased emphasis on such sketches, the difference being 0.9 of an IQ point.
Students in the control group, on the other hand, received higher marks in geometry, on an average, than did students in the experimental group, the difference being 0.5, or one-fourth of a letter mark for each semester.

In following the usual methodology of analysis of covariance, the sums of squares and cross-products in deviation form were obtained from the original sums shown in the Appendix. These sums of squares and cross-products were classified by sources of variation into (1) control-experimental, (2) sex, (3) interaction and (4) within subgroups.

Four series of values were needed for the solution of normal equations. One series was based on the within subgroups sums of squares and cross-products. The other three were obtained by adding the sums of squares and cross-products for each of the main effects and interaction to those computed for within the subgroups.

These normal equations were solved simultaneously and the resulting equations in deviation form for predicting achievement in men and events in chemistry from IQ's and geometry marks, together with the analysis of regression for each of the four sets of normal equations, are shown in Table 20.

The usefulness of the control factors was indicated by a coefficient of multiple correlation of 0.589. The relative contribution of the IQ and the geometry mark in the prediction of achievement in men and events was 32 percent and 68 percent, respectively.

The analysis of covariance is shown in Table 21. There is a significant difference in achievement in men and events in chemistry between control and experimental groups. Sex differences in such achievement between boys and girls was not demonstrated. Evidence did
Table 20
Analysis of Regression of Achievement in Men and Events in Chemistry

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression¹</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom for Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within plus Control-Experimental</td>
<td>( y = 0.21183x_1 + 1.12871x_2 )</td>
<td>8728.03 2115.34 6612.69</td>
<td>155</td>
</tr>
<tr>
<td>Within plus Sex</td>
<td>( y = 0.14576x_1 + 1.65293x_2 )</td>
<td>6960.07 2407.84 4552.23</td>
<td>155</td>
</tr>
<tr>
<td>Within plus Interaction</td>
<td>( y = 0.13863x_1 + 1.71559x_2 )</td>
<td>7178.79 2422.64 4756.15</td>
<td>155</td>
</tr>
<tr>
<td>Within Alone</td>
<td>( y = 0.14785x_1 + 1.6623x_2 )</td>
<td>6952.47 2411.41 4541.06</td>
<td>154</td>
</tr>
</tbody>
</table>

¹\( y \) = deviation score for achievement in men and events in chemistry.

\( x_1 \) = deviation IQ.

\( x_2 \) = deviation geometry mark.
Table 21

Analysis of Covariance of Achievement in Men and Events in Chemistry

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>2171.63</td>
<td>2071.63</td>
<td>8.38**</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>11.17</td>
<td>11.17</td>
<td>0.61</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>215.09</td>
<td>215.09</td>
<td>2.70**</td>
</tr>
<tr>
<td>Within</td>
<td>154</td>
<td>1541.06</td>
<td>29.69</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5% level.  ** Significant at 1% level.

indicate, shown by the highly significant t-value for interaction, that girls profit more than boys with increased emphasis upon biographical sketches as an inspection of the adjusted mean values will show.

By using analysis of covariance, as shown in Table 21, the within mean square was reduced to 29.69 from the 44.57 shown in the analysis of variance in Table 19. The foregoing reduced the denominator term in the test of significance and increased the t-value. The significant t-value for interaction in analysis of variance is shown to be highly significant by the analysis of covariance.

The control-experimental mean square was 1775.56 in the analysis of variance and 2071.63 in the analysis of covariance. If the two groups had identical mean IQ's and mean geometry marks, these two mean squares would be identical. The larger mean square was found by covariance.
analysis indicating that, whichever group was superior without control, its superiority was increased by considering the IQ and geometry marks for each student.

The mean score for the experimental group was 30.25 and for the control group it was 23.59 as shown in Table 18. The difference between the means was 6.66. When the differences between the mean IQ's and between the mean geometry marks are substituted in the within regression equation the adjusted mean difference would be 0.70 greater. Thus, if the two groups had identical mean IQ's and mean geometry marks, students with increased emphasis on biographical sketches, on an average, would have excelled students in the control group by 7.36.

This adjusted mean difference represents 0.98 of a standard score unit. Thus, a student making normal progress who would be in the 50th percentile rank in the control group, would be in the 84th percentile rank in a group with increased emphasis upon biographical sketches.

It was not unexpected to find evidence in this study that the use of biographical sketches increases the achievement in men and events in chemistry since in the experimental group 14 percent of the available class time was used for emphasis of such information.
VII. SCIENTIFIC METHOD

A traditional objective in science courses has been the degree to which a student acquires a knowledge of the scientific method. The criterion of achievement in scientific method, for purposes of this study, was limited to the total score on a 23-item test "Part II and Part III -- Ability to Draw Conclusions", shown in the Appendix.

In this test items 1-15 inclusive were selected from a test used by TerKeurst and Bugbee. Items 16-23 inclusive were selected from a test used by Teichman.

The foregoing multiple-choice items, numbered 1-23 inclusive were scored one point per item. With the 160 students included in this study, the scores of correct responses varied from 10 to 23 with a mean of 18.70 and a standard deviation of 2.8. The estimated coefficient of reliability was 0.53.

The mean scores for boys and girls, with and without increased emphasis on biographical sketches, are shown in Table 22. In the sample of 160 students the experimental group, with increased emphasis on biographical sketches, was slightly inferior to the control group in achievement in scientific method. The mean score for boys was similar to that for girls.


2TEICHMAN, LOUIS. "The Ability of Science Students to Make Conclusions." Science Education. 28: 263-279; December 1944.
Table 22
Mean Scores of Achievement in Scientific Method

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Both</td>
</tr>
<tr>
<td>Experimental</td>
<td>18.50</td>
<td>18.07</td>
<td>18.34</td>
</tr>
<tr>
<td>Control</td>
<td>18.98</td>
<td>19.20</td>
<td>19.06</td>
</tr>
<tr>
<td>Total</td>
<td>18.74</td>
<td>18.63</td>
<td>18.70</td>
</tr>
</tbody>
</table>

The differences in means, shown in Table 22, may have resulted from variations such as are to be expected when random samples are drawn from a single population. A preliminary test of significance, disregarding known individual differences in student aptitude, was made from an analysis of variance shown in Table 23. No significant differences were found.

A more satisfactory test of significance may be obtained from an analysis of covariance in which some degree of control of student aptitude can be accomplished. The purpose of the analysis of covariance is twofold, i.e., (1) to adjust the sums of squares for the main effects and the control variables and (2) to render tests of significance more sensitive. The former will be reflected in some changes in the magnitude of the sums of squares for the main effects and the interaction of the within sum of squares, the amount of the reduction being contingent...
upon the degree of relationship between the criterion and the battery of control variables.

An analysis of covariance was made so that tests of significance could be made with the use of a battery of two control variables, the IQ and the geometry mark. Students in the experimental group, receiving special emphasis on biographical sketches, had higher IQ's on an average, than did students in the control group, not receiving an increased emphasis on such sketches, the difference being 0.9 of an IQ point. Students in the control group, on the other hand, received higher marks in geometry, on an average, than did students in the experimental group, the difference being 0.5, or one-fourth of a letter mark for each semester.

The usual methodology of covariance analysis was followed. As a
preliminary step, sums of squares and cross-products in deviation form were obtained from the original sums shown in the Appendix. These sums of squares and cross-products were classified by sources of variation into (1) control-experimental, (2) sex, (3) interaction and (4) within subgroups.

Four series of values were needed for the solution of the normal equations. One series was based on the within subgroups sums of squares and cross-products. The other three were obtained by adding the sums of squares and cross-products for each of the main effects and interaction to those computed for within the subgroups.

These normal equations were solved simultaneously and the resulting equations in deviation form for predicting achievement in scientific method from the IQ and geometry mark are shown in Table 24, together with the analysis of regression for each of the four sets of normal equations.

The usefulness of the control factors was indicated by a coefficient of multiple correlation of 0.58. The relative contribution of the IQ and geometry mark in the prediction of achievement in scientific method was 58 percent and 42 percent, respectively.

The analysis of covariance is shown in Table 25. There is no significant difference in achievement in scientific method between control and experimental groups. Sex difference in such achievement between boys and girls was not demonstrated. Evidence failed to indicate that either boys or girls profited more, or less, with increased emphasis upon biographical sketches, as indicated by the nonsignificance of the interaction.
### Table 2h

**Analysis of Regression of Achievement in Scientific Method**

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom for Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within plus Control-Experimental</td>
<td>$y = 0.08735x_1 + 0.4854x_2$</td>
<td>1233.17</td>
<td>373.98</td>
</tr>
<tr>
<td>Within plus Sex</td>
<td>$y = 0.09070x_1 + 0.43353x_2$</td>
<td>1212.57</td>
<td>357.30</td>
</tr>
<tr>
<td>Within plus Interaction</td>
<td>$y = 0.09360x_1 + 0.43628x_2$</td>
<td>1216.15</td>
<td>366.84</td>
</tr>
<tr>
<td>Within Alone</td>
<td>$y = 0.09245x_1 + 0.43291x_2$</td>
<td>1212.15</td>
<td>366.12</td>
</tr>
</tbody>
</table>

1. $y =$ deviation score for achievement in scientific method.
2. $x_1 =$ deviation IQ.
3. $x_2 =$ deviation geometry marks.
Table 25

Analysis of Covariance of Achievement in Scientific Method

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Residuals</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>13.16</td>
<td>13.16</td>
<td>1</td>
<td>1.55</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>9.24</td>
<td>9.24</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>3.28</td>
<td>3.28</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>154</td>
<td>846.03</td>
<td>5.49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adjustment of the means in the experimental and the control groups would not be appropriate since no significant difference in the means was shown to exist. The point of view has sometimes been expressed that emphasizing biographies increases knowledge of the scientific method. Evidence in this study did not confirm this point of view. The suitability of the instrument used for evaluation of the objective of achievement in scientific method must be weighed in consideration of the confidence which can be placed in these inferences.
VIII. SCIENTIFIC ATTITUDE

A traditionally important objective for many science courses has been the degree to which a student acquires a scientific attitude. Although the definition of scientific attitude is apparently unique for each scientist as well as for each teacher, for purposes of this study, the criterion for scientific attitude was limited to the score on a 31-item test. These 31 items, 24-54 inclusive, appear in "Part IV -- An Experimental Scale" which is shown in the Appendix.

The first 12 items were selected from a scale constructed by Howard and Robertson.¹ The next 3 items were suggested by items in a scale constructed by Curtis² for measuring the scientific attitude. The last 16 items were constructed by the investigator.

All the items were multiple choice items with the possible choices (A) strongly agree, (B) agree, (C) undecided, (D) disagree and (E) strongly disagree. They were scored, not right or wrong, but rather 1, 2, 3, 4, 5 or 1, 2, 3, 4, 5 depending upon whether (A) strongly agree, was the most scientific or the least scientific of the ideas expressed. Five points were given for the most scientific of the attitudes and one point for the least. With the 160 students included in this study, the scores varied from 93 to 138 with a mean of 112.6 and a standard deviation

¹HOWARD, FREDERICK T., AND ROBERTSON, M. L. "Scaling the Intangibles." Science Education. 24: 249-255; October 1940.

of 11.2 The estimated coefficient of reliability was 0.93 for the scores of scientific attitude.

In the sample of 160 students the scientific attitude of the experimental group, with biographical sketches, was somewhat inferior to the scientific attitude of the control group. No sex difference in scientific attitude was apparent from Table 26.

Table 26

Mean Scores of Scientific Attitude

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Both</td>
</tr>
<tr>
<td>Experimental</td>
<td>110.18</td>
<td>111.27</td>
<td>110.58</td>
</tr>
<tr>
<td>Control</td>
<td>111.76</td>
<td>114.33</td>
<td>114.60</td>
</tr>
<tr>
<td>Total</td>
<td>112.47</td>
<td>112.80</td>
<td>112.60</td>
</tr>
</tbody>
</table>

A preliminary test of significance, disregarding known individual differences in student aptitude, was made from an analysis of variance shown in Table 27. Evidence from this analysis failed to disprove the null hypothesis that sex differences do not exist and that boys and girls respond the same to the control and experimental treatment. However, the achievement in scientific attitude was significantly lower, at the 5% level, for the experimental group with emphasis on biographies.
Table 27
Analysis of Variance of Scientific Attitude

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>644.01</td>
<td>644.01</td>
<td>2.28*</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>4.08</td>
<td>4.08</td>
<td>0.18</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>21.47</td>
<td>21.47</td>
<td>0.42</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>19363.03</td>
<td>124.12</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>20032.59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5% level.

The foregoing inferences were drawn without regard for known individual differences in student aptitude.

A more satisfactory test of significance may be obtained from an analysis of covariance in which some degree of control of student aptitude can be accomplished. The purpose of the analysis of covariance is twofold, i.e., (1) to adjust the sums of squares for the main effects and the interaction for group differences in the means of the control variables and (2) to render tests of significance more sensitive. The former will be reflected in some changes in the magnitude of the sums of squares for the main effects and the interaction of the within sum of squares, the amount of the reduction being contingent upon the degree of relationship between the criterion and the battery of control variables.

An analysis of covariance was made so that tests of significance
could be made with the use of a battery of two control variables, the IQ and the geometry mark. Students in the experimental group, receiving special emphasis on biographical sketches, had higher IQ's on an average than did students in the control group, not receiving an increased emphasis on such sketches, the difference being 0.9 of an IQ point. Students in the control group, on the other hand, received higher marks in geometry, on an average, than did students in the experimental group, the difference being 0.5, or one-fourth of a letter mark for each semester.

The usual methodology of covariance analysis was followed. As a preliminary step, sums of squares and cross-products in deviation form were obtained from the original sums shown in the Appendix. These sums of squares and cross-products were classified by sources of variation into (1) control-experimental (2) sex, (3) interaction and (b) within subgroups.

Four series of values were needed for the solution of the normal equations. One series was based on the within subgroups sums of squares and cross-products. The other three were obtained by adding the sums of squares and cross-products for each of the main effects and interaction to those computed for within the subgroups.

These normal equations were solved simultaneously and the resulting equations in deviation form for predicting achievement in scientific attitude from IQ and geometry mark are shown in Table 28, together with the analysis of regression for each of the four sets of normal equations.

The usefulness of the control factors was indicated by a coefficient of multiple correlation of 0.475. The relative contribution of the IQ
Table 28

Analysis of Regression of Scientific Attitude

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression(^1)</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom for Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>Regression</strong></td>
</tr>
<tr>
<td>Within plus Control-Experimental</td>
<td>(y = 0.26836x_1 + 1.91196x_2)</td>
<td>20007.04</td>
<td>458.74</td>
</tr>
<tr>
<td>Within plus Sex</td>
<td>(y = 0.29480x_1 + 1.61231x_2)</td>
<td>19367.12</td>
<td>431.78</td>
</tr>
<tr>
<td>Within plus Interaction</td>
<td>(y = 0.29522x_1 + 1.67960x_2)</td>
<td>19384.50</td>
<td>4359.10</td>
</tr>
<tr>
<td>Within Alone</td>
<td>(y = 0.29838x_1 + 1.66153x_2)</td>
<td>19363.03</td>
<td>4359.54</td>
</tr>
</tbody>
</table>

\(^1\) \(y\) = deviation score for scientific attitude.

\(x_1\) = deviation IQ.

\(x_2\) = deviation geometry mark.
and geometry mark in the prediction of scientific attitude was 53 percent and 47 percent, respectively.

The analysis of covariance is shown in Table 29. The control group excelled the experimental group in scientific attitude by an amount which was significant at the 5% level. Sex differences in such achievement between boys and girls was not demonstrated. Evidence did not show that either boys or girls suffered more, or less, with increased emphasis upon biographical sketches, as indicated by the nonsignificance of the interaction.

Table 29
Analysis of Covariance of Scientific Attitude

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>454.81</td>
<td>454.81</td>
<td>2.16*</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>38.85</td>
<td>38.83</td>
<td>0.63</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>25.91</td>
<td>25.91</td>
<td>0.52</td>
</tr>
<tr>
<td>Within</td>
<td>154</td>
<td>15003.49</td>
<td>97.43</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5% level.
The within mean square of the analysis of variance, shown as 124.12 in Table 27, was reduced to 97.43 for the analysis of covariance shown in Table 29, thus reducing the denominator term used in the test for significance.

The control-experimental mean square was 64.40 in the analysis of variance and 45.81 in the analysis of covariance. If the two groups had identical mean IQ's and mean geometry marks, these two mean squares would be identical. The smaller mean square was found in covariance, indicating that, whichever group was superior without control, its superiority was decreased by considering the IQ and geometry mark for each student.

The mean score for the experimental group was 110.53 and for the control group it was 114.76, as shown in Table 26. The difference between the means is 4.28. When the differences between the mean IQ's and between the mean geometry marks are substituted in the within regression equation the adjusted mean difference would be 0.56 smaller. Thus if the two groups had identical mean IQ's and mean geometry marks, students without increased emphasis on biographies, on an average, would have excelled students with increased emphasis on biographies by 3.62.

Although some teachers of chemistry have maintained stressing biographical information increases scientific attitude, the findings of this study do not substantiate that point of view. Confidence in these findings can be justified only in terms of the suitability of the measuring device used for the criterion. Literature in the field recognizes a dearth of measures of scientific attitude.
IX. SCIENTIFIC INTEREST

All chemistry teachers, no doubt, believe that increasing scientific interest is one of the desired objectives of high school chemistry instruction. The scientific interest scores on the Kuder Preference Record Form CH furnished the information from which the criterion was obtained. The increase in scientific interest scores, before and after chemistry instruction, was chosen as the criterion of this objective.

The criterion scores were positive whenever a gain in scientific interest occurred and negative whenever a loss in such interest occurred. For the entire group, 109 criterion scores were positive and 51 negative. The mean change-in-interest score was 3.39. Scientific interest increased during the period of chemistry instruction for these 160 students. The standard deviation of these criterion scores was 12.65, indicating the magnitude of the interest changes which occurred.

A t-test was made to test the significance this mean change of 3.39 from no mean change. The standard error of the mean was 0.73 which produced a t-value of 4.35, significant at the 1% level. Thus, the probability of obtaining a numerical mean change of 3.39 or larger from a population in which no change occurs is extremely remote, much less than one in a thousand.

Information was not available for a group who did not take chemistry with respect to a Kuder score obtained at the same time the post-score was obtained for the 160 students who took chemistry. Changes in interests may have resulted from chemistry instruction; from maturity;
from greater demand for well-educated personnel in the changing social order; or some combination of the three factors. Although no evidence is available to isolate the contribution of these three factors to scientific interest changes, nevertheless, the magnitude of the t-value obtained leads one to believe that chemistry instruction increases scientific interest.

The magnitude of the shifts in scientific interest among high school chemistry students suggests speculation concerning the reasons for such shifts. It may be that student shifts result from variation in achievement in chemistry. With the 160 students, the change in scientific interest was found to be related to achievement in the fundamentals of chemistry as described in Section V. The coefficient of correlation was 0.107, which is nonsignificant. No other attempt was made, in this study, to obtain correlates with scientific interest changes.

Changes in scientific interests were evaluated between the control and experimental groups, when stratified by sex. The mean changes in interest are shown in Table 30. An analysis of the variances is shown in Table 31. No significance differences were found.

No analysis of covariance was attempted since obtaining the criterion scores by subtraction automatically controlled on IQ and geometry mark as well upon other individual differences among the students.

If the Kuder scores are valid evidences of scientific interests certain inferences seem justified under conditions prevailing in this study. Greater scientific interest results from high school chemistry
Table 30

Mean Change Scores on Kuder Scientific Interest

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Both</td>
</tr>
<tr>
<td>Experimental</td>
<td>2.80</td>
<td>5.47</td>
<td>3.80</td>
</tr>
<tr>
<td>Control</td>
<td>2.74</td>
<td>3.40</td>
<td>2.99</td>
</tr>
<tr>
<td>Total</td>
<td>2.77</td>
<td>4.43</td>
<td>3.39</td>
</tr>
</tbody>
</table>

Table 31

Analysis of Variance of Changes in Kuder Scientific Interest

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>26.141</td>
<td>26.141</td>
<td>0.52</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>103.75</td>
<td>103.75</td>
<td>1.03</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>37.75</td>
<td>37.75</td>
<td>0.62</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>15384.19</td>
<td>97.54</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>15552.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Instructor. Increased emphasis on biographical sketches has not been demonstrated to produce greater scientific interest.
X. SCIENCE ACTIVITIES AND AMBITIONS

Interest in science, to some extent, can be inferred from the science activities in which an individual engages and from his educational ambitions. A questionnaire was prepared to assemble information consisting of four items. These items were (1) Do you like to read science articles in newspapers and/or magazines?; (2) Rate high school chemistry with other high school courses you have taken?; (3) Do you plan to spend four years or more in some college?; and (4) If you expect to go to college, check one of these. Five responses, unique for each of the four items, were provided for checking.

Criterion scores for science activities and ambitions were obtained by summing, for all four items, the coded values of 1, 2, 3, 4 or 5, for each item. No attempt has been made to appraise the validity or reliability of this criterion.

The chemistry students were classified by sex and experimental-control groups according to the frequency of reading science articles in newspapers and magazines as shown in Table 32. Coded values of 1, 2, 3, 4 or 5 were assigned to the responses as indicated.

No student reported that he was a nonreader of science articles. Of these 160 students, 85 percent reported reading such articles sometimes or frequently. The mean scores of the coded values were tested for significance and the analysis of variance shown in Table 33. No significant difference was found between the control and experimental groups. Thus, the frequency of reading science articles could not be
Table 32
Frequency of Reading Science Articles in Newspapers and Magazines

<table>
<thead>
<tr>
<th>Response</th>
<th>Code</th>
<th>Experimental</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seldom</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>3</td>
<td>20</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>Quite Often</td>
<td>4</td>
<td>18</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Very Much</td>
<td>5</td>
<td>10</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total Students</td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3.72</td>
<td>3.10</td>
<td>3.56</td>
</tr>
</tbody>
</table>

Table 33
Analysis of Variance for Frequency of Reading Science Articles in Newspapers and Magazines

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental-Control</td>
<td>1</td>
<td>0.2250</td>
<td>0.2250</td>
<td>0.67</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>9.6267</td>
<td>9.6267</td>
<td>5.61**</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.4816</td>
<td>0.4816</td>
<td>0.99</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>77.2667</td>
<td>0.4953</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>87.6000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level.
demonstrated to be a function of the emphasis upon biographical sketches. It is not unexpected that boys read more science articles than do girls, the difference being significant at the 1% level.

The chemistry students were classified by sex and experimental-control groups according to the student rating of interest in chemistry courses with that in other high school courses as shown in Table 34. An inspection of this table indicates clearly the high reported interest in chemistry as contrasted to that in other high school course, approximately 9 in every 10 student indicating a rating of interesting or highly interesting.

Table 34

Student Ratings of Chemistry with Other Courses

<table>
<thead>
<tr>
<th>Response</th>
<th>Code</th>
<th>Experimental</th>
<th>Control</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
</tr>
<tr>
<td>Very uninteresting</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Uninteresting</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Can not decide</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Interesting</td>
<td>4</td>
<td>22</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>Highly Interesting</td>
<td>5</td>
<td>24</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Total Students</td>
<td></td>
<td>50</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Mean Rating</td>
<td></td>
<td>4.36</td>
<td>4.20</td>
<td>4.14</td>
</tr>
</tbody>
</table>
It may be that these responses are biased since the information was collected by the chemistry teacher. Such bias, if present, apparently is of little consequence in comparing the experimental and the control groups since each group likely would be equally biased.

An analysis of variance was made for student ratings of chemistry with other courses as shown in Table 35. No significant differences were found. Thus, student ratings of chemistry with other courses could not be demonstrated to be a function of the emphasis upon biographical sketches.

Table 35

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental-Control</td>
<td>1</td>
<td>1.0563</td>
<td>1.0563</td>
<td>1.05</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.3605</td>
<td>0.3605</td>
<td>0.61</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.1203</td>
<td>0.1203</td>
<td>0.35</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>149.8067</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>151.3438</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The students were next classified by sex and experimental-control groups according to intentions of later college graduation as shown in Table 36. An inspection of this table reveals that approximately 9 of every 10 students expect to continue their education, at least to college graduation. This number of college-bound high school seniors, on first thought, may appear to be high. It is customary for most Ames High School graduates, particularly those with chemistry credit, to go to college.

Table 36
Intentions of College Graduation

<table>
<thead>
<tr>
<th>Response</th>
<th>Code</th>
<th>Experimental</th>
<th>Control</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
</tr>
<tr>
<td>Definitely Not</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probably Not</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Do not Know</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Probably</td>
<td>4</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Yes, Definitely</td>
<td>5</td>
<td>34</td>
<td>21</td>
<td>39</td>
</tr>
<tr>
<td>Total Students</td>
<td></td>
<td>50</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>4.66</td>
<td>4.50</td>
<td>4.74</td>
</tr>
</tbody>
</table>
An analysis of variance for intentions of college graduation is shown in Table 37. No significant differences were found. Thus, intentions of college graduation could not be demonstrated to be a function of emphasis upon biographical sketches in chemistry instruction.

The students were classified by sex and experimental-control groups according to the emphasis on science which they expected to place in a later college curriculum as shown in Table 38. For these 160 students it was anticipated that science will occupy a prominent place in their later college education.

Table 37

Analysis of Variance for Intentions of College Graduation

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>0.7563</td>
<td>0.7563</td>
<td>1.24</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.2605</td>
<td>0.2605</td>
<td>0.51</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.2203</td>
<td>0.2203</td>
<td>0.47</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>76.2067</td>
<td>0.4885</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>77.4438</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 38
Plans for Emphasis on Science in College

<table>
<thead>
<tr>
<th>Major</th>
<th>Code</th>
<th>Experimental</th>
<th></th>
<th>Control</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Some Field Requiring No Science</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>In Some Field Requiring Little Science</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>Non-Science With Science Minor</td>
<td>3</td>
<td>10</td>
<td>15</td>
<td>11</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>Science Not Chemistry</td>
<td>4</td>
<td>21</td>
<td>3</td>
<td>28</td>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>Chemistry</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Total Students</td>
<td></td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>30</td>
<td>160</td>
</tr>
</tbody>
</table>

Mean Emphasis on Science 3.54 2.97 3.44 2.90 3.28

An analysis of variance of plans for emphasis on science in college is shown in Table 39. It is not unexpected to find that boys plan to include more science in their college curricula than girls. The difference in this respect was highly significant, the t-value being 3.44. Difference in plans for emphasis on science could not be demonstrated to be a function of the emphasis upon biographical sketches in high school chemistry instruction.

Responses to each of the four items may reflect an interest in chemistry and other sciences. If this relationship is postulated, a
Table 39
Analysis of Variance for Plans for Emphasis on
Science in College

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>0.3062</td>
<td>0.3062</td>
<td>0.55</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>11.6204</td>
<td>11.6204</td>
<td>3.41**</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>0.0104</td>
<td>0.0104</td>
<td>0.10</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>156.4067</td>
<td>1.0027</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>168.3137</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level.

A better measure of science interest could be obtained by combining the evidences obtained from all four items in the usual manner of test construction. The scores when combined varied from 8 to 20 with a mean of 15.61 and a standard deviation of 2.25. These criterion scores evaluate an objective here designated as science activities and ambitions.

The mean scores for boys and girls, with and without increased emphasis on biographical sketches, are shown in Table 40. In the sample of 160 students, a slight advantage was noted for the group in which biographical sketches were emphasized. Attainment of this objective was more pronounced for boys than for girls.
Table I0

Mean Scores for Science Activities and Ambitions

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Both</td>
</tr>
<tr>
<td>Experimental</td>
<td>16.28</td>
<td>14.77</td>
<td>15.71</td>
</tr>
<tr>
<td>Control</td>
<td>15.88</td>
<td>14.90</td>
<td>15.51</td>
</tr>
<tr>
<td>Total</td>
<td>16.08</td>
<td>14.83</td>
<td>15.61</td>
</tr>
</tbody>
</table>

A preliminary test of significance of the differences between means was made by an analysis of variance as shown in Table 11. The difference between the control and experimental groups was nonsignificant. Boys excelled the girls in interest in science as revealed by the objective of science activities and ambitions. These inferences were drawn without a consideration of individual differences in student ability.

An analysis of covariance was then made as has been done with objectives evaluated in foregoing sections. The usefulness of the control factors was indicated by a coefficient of multiple correlation of 0.383. The relative contribution of the IQ and the geometry mark in the prediction of criterion scores for science activities and ambitions was 15 percent and 85 percent, respectively.

The four regression equations for the prediction of scores for science activities and ambitions from IQ's and geometry marks, together with sums of squares for regression and residuals are shown in Table I2.
Table 4.1
Analysis of Variance for Science Activities and Ambitions

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0.65</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>58</td>
<td>58</td>
<td>3.51**</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0.80</td>
</tr>
<tr>
<td>Within</td>
<td>156</td>
<td>74.1</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>80.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level.

The analysis of covariance is shown in Table 4.3. Individual differences among students in science activities and ambition, as here measured, was not demonstrated to be a function of the emphasis on biographical sketches. Boys are more interested than girls in science activities and ambitions as indicated by a t-value of 4.33, significant far beyond 1% level.
Table 42
Analysis of Regression of Scores for Science Activities and Ambitions

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression (^1)</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom for Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Regression</td>
<td>Residuals</td>
</tr>
<tr>
<td>Within Alone</td>
<td>(y = 0.01679x_1 + 0.42268x_2)</td>
<td>71.1</td>
<td>108</td>
</tr>
<tr>
<td>Within plus Control-Experimental</td>
<td>(y = 0.02023x_1 + 0.39396x_2)</td>
<td>71.3</td>
<td>104</td>
</tr>
<tr>
<td>Within plus Sex</td>
<td>(y = 0.0171x_1 + 0.39571x_2)</td>
<td>800</td>
<td>90</td>
</tr>
<tr>
<td>Within plus Interaction</td>
<td>(y = 0.01793x_1 + 0.41604x_2)</td>
<td>71.4</td>
<td>108</td>
</tr>
</tbody>
</table>

\(^1\) \(y = \) deviation score for Science Activities and Ambitions.

\(x_1 = \) deviation IQ.

\(x_2 = \) deviation geometry marks.
### Table 43

Analysis of Covariance in Science Activities and Ambitions

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Experimental</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>1.21</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>77</td>
<td>77</td>
<td>4.33**</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0.85</td>
</tr>
<tr>
<td>Within</td>
<td>154</td>
<td>636</td>
<td>4.1</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level.
XI. SUMMARY

The purpose of this study was to reveal objective evidence regarding the effectiveness of using biographical sketches in the teaching of high school chemistry.

For purposes of this study, the control-group sample consisted of 50 high school senior boys and 30 high school girls, as did the experimental-group sample. The experimental group excelled the control group in mean IQ by the nonsignificant amount of 0.9 IQ points, whereas the experimental group was inferior to the control group in mean geometry mark by the nonsignificant amount of 0.5 grade points. Neither group was highly atypical when compared with Kuder norms of scientific interest or with national norms for IQ's of high school seniors.

All students in the control and experimental groups took chemistry at Ames High School, Ames, Iowa, in the same classroom and with the same teacher. During the experiment the time available for each chemistry unit was the same for each group. Teaching methods were the same with the exception that in the experimental group men and events in chemistry were emphasized by the presentation of biographical sketches and in the control group no such emphasis occurred.

Evaluated in this study were six objectives of the high school chemistry course as follows:

- Fundamentals of high school chemistry
- Men and events in chemistry
- Scientific method
- Scientific attitude
- Scientific interest
- Science activities and ambitions
For five of the six objectives, the exception being the objective of scientific interest, mean differences between the experimental and control groups were tested by the analysis of covariance technique. The IQ and geometry mark were control variables in the analysis of covariance tests of significance and stratification was on the basis of sex.

The criterion for the evaluation of achievement in fundamentals of chemistry was the total score on seven objective unit tests. If the IQ's and the geometry marks were controlled, the students with increased emphasis on biographical sketches exceeded students in the control group by three-fourths of a standard score unit. With regard to the foregoing objective, both boys and girls profit from the use of biographical sketches and girls profit more than boys.

It was unexpected to find the magnitude of the effectiveness so great when evaluated in terms of achievement in the fundamentals of chemistry since the time spent with biographical sketches reduced the class time spent in other learning activities. With regard to the foregoing objective, both boys and girls profit from the use of biographical sketches and they profit equally.

The criterion for the evaluation of achievement in men and events in chemistry was limited to the score on a 53-item, multiple-choice test designed for that purpose. If the control and experimental groups had identical mean IQ's and mean geometry marks, students with increased emphasis on biographical sketches, on an average, would have excelled students in the control group by 0.98 of a standard score. Thus, a
student making normal progress who would be in the 50th percentile rank in the control group, would be in the 84th percentile rank in a group with increased emphasis upon biographical sketches.

It was not unexpected to find evidence in this study that the use of biographical sketches increases the achievement in men and events in chemistry since in the experimental group 14 percent of the available class time was used for emphasis of such information. With regard to the foregoing objective boys and girls profit equally from the use of biographical sketches.

The criterion for the evaluation of achievement in scientific method was limited to the score on a 23-item, multiple-choice test designed for that purpose. No significant t-values resulted from the analysis of covariance used to test the difference in the means of the control and experimental groups with regard to achievement in scientific method. The findings of this study did not tend to substantiate the point of view that emphasizing biographies increases knowledge of the scientific method.

The criterion for the evaluation of scientific attitude was limited to the score on a 31-item, multiple-choice test designed for that purpose. In this evaluation, the control group, without biographical sketches, excelled the experimental group by an amount which yielded a significant t-value, at the 5% level of confidence, in the analysis of covariance. Although some chemistry teachers have maintained stressing biographical information increases achievement in scientific attitude there was insufficient evidence in the findings of this study to substantiate that point of view.
The criterion for the evaluation of scientific interest was the shift in scientific interest before and after chemistry instruction. The Kuder Preference Record, form CH, furnished the required information. The difference between a pre-test and a post-test automatically controls on individual differences among the students. A positive mean change-in-interest score, demanded by the null hypothesis, produced a t-value of 4.35, highly significant at the 1% level. The inference that greater scientific interest results from high school chemistry instruction seems justified. Increased emphasis on biographical sketches was not demonstrated to produce greater scientific interest.

The criterion for the evaluation of achievement in science activities and ambitions was the total score on a questionnaire which consisted of 4 items with regard to (1) reading of science articles, (2) rating of high school chemistry, (3) college plans (h) college major. Individual differences among the students in science activities and ambitions as here measured, and as tested for significance by the analysis of covariance, were not demonstrated to be a function of the emphasis on biographical sketches. As would be expected, boys are more interested than girls in science activities and ambitions as indicated by a t-value of 4.33, significant far beyond the 1% level.

In searching for objective evidence regarding the effectiveness of using biographical sketches in the teaching of high school chemistry, it was demonstrated by this study that an increased emphasis upon biographical sketches results in an increase of (1) achievement in fundamentals of chemistry and (2) achievement in men and events in chemistry. It was not demonstrated in this study that an increased emphasis upon
biographical sketches results in an increase in (1) achievement in scientific method, (2) scientific attitude, (3) scientific interest and (4) science activities and ambitions. Implications for the teaching of high school chemistry, resulting from the conclusions and discussion in the evaluation of the six objectives studied, include the desirability of emphasis upon biographical sketches in high school chemistry instruction.
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XIII. APPENDIX

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<td>K. Sums of Squares and Cross-Products</td>
<td>149</td>
</tr>
</tbody>
</table>
A. Test of Chemical History and Biographies

INSTRUCTIONS: You have been given two answer sheets. Label at the top a FIRST answer sheet and a SECOND answer sheet. Put your name on both.

The FIRST answer sheet is for Part I of this test.

The SECOND answer sheet is for Parts II, III and IV of this test.

<table>
<thead>
<tr>
<th>Part</th>
<th>Chemical History and Biographies</th>
<th>(1-53)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
<td>Scientific Method</td>
<td>(1-15)</td>
</tr>
<tr>
<td>Part</td>
<td>Ability to Draw Conclusions</td>
<td>(16-23)</td>
</tr>
<tr>
<td>Part</td>
<td>An Experimental Scale</td>
<td>(24-54)</td>
</tr>
</tbody>
</table>

Total for all parts 107 items

You will have the full class period for this test, which means about 30 seconds per item. You will return to the difficult items if time permits.

Part I
(First answer sheet)

Chemical History and Biographies

DIRECTIONS: Select the one best answer unless otherwise instructed.

1. The idea that all matter is composed of "the elements" earth, air, fire and water was common among learned men until .
   a. 200 BC, b. 200 AD, c. 1000 AD, d. 1700 AD, e. 20th century.

2. The theory that all burnable substances contain PHLOGISTON was suggested first by .
   a. Becher, a German scientist, b. Priestley, an English amateur scientist, c. Lavoisier, eminent French chemist, d. Scheele, a Swedish pharmacist, e. None of the above.

3. What is the significance of the term "philosopher's stone"?
   a. A fictitious element, b. A compound that used to exist but does not now, c. Once used by scientists to explain burning, d. Alchemists thought it would turn
other matter into gold, e. None of the above explain the significance.

4. Socrates, a learned Greek teacher tried to discover about matter by
   a. Reading literature of his day, b. Doing research,
   c. Better laboratory equipment, d. logical thinking,
   e. all of these methods.

5. Joseph Priestley left England and spent his later years in Pennsylvania. Which best explains his reasons?
   c. Political persecution in England, d. (b) and (c), e. A fine financial offer in Pennsylvania.

6. Adhering to a scientist's theory of 300 years ago, a substance would burn if it contained phlogiston which could be detected as ________.

7. ________ said, "Burning is the chemical union of a burnable substance with oxygen".

8. When Priestley discovered a gas that was later named oxygen, he acted like a true scientist by ________.
   a. Discussing it with Lavoisier as soon as he got to France, b. Keeping the information secret, c. Publishing a book so the world would know immediately, d. Giving the information to the newspapers, e. (c) and (d).

9. Select the method of reasoning which, according to Jaffe, is to a great extent responsible for the success of the scientific method.

10. A method of reasoning, in which inferences and conclusions are drawn from a general statement, is called ________.

11. Francis Bacon was the first person to popularize the ________ method of reasoning.
12. The method of reasoning that Aristotle commonly used is the method of _____.

13. A method of reasoning that involves collection of facts regarding a problem and testing them toward the evolution of a principle or law is called _____.

14. _____ is credited with the discovery of hydrogen.
   a. Lavoisier, b. Priestley, c. Scheele, d. Hertz, e. None of these.

15. According to Jaffe, establishing accurate _____ is perhaps the greatest function of science.

16. The first clue to prove the phlogiston theory correct or incorrect was that many substances, when burned, _____.
   a. Lose weight, b. Weigh the same, c. Gain weight, d. Disappear, e. None of these.

17. Oxygen was discovered by _____, according to modern historians.
   a. Lavoisier, b. Priestley, c. Phlogiston, d. Scheele, e. None of these listed.

18. Morley (1838-1923) spent over 10 years of his life in accurately determining the relative combining weights of oxygen and hydrogen. In what country did he do this work?

19. Around 1800 _____ developed and used the atomic theory.

20. Alchemists used signs and symbols _____.
   a. To keep outsiders from understanding their work, b. to help people know what they were doing, c. And agreed so
well among themselves we still use many of their symbols,
d. To make their work easier, e. To make their work more
exact.

21. Select the man who invented a simple system of chemical notation, a
Swedish orphan who introduced his system in 1814.


22. Jaffe quotes ______ as writing, "As the usefulness and accuracy of
chemistry depend entirely upon the determination of the weights of
the ingredients and products, too much precision cannot be employed
in this part of the subject, and for this purpose we must be pro-
vided with good instruments".

   a. Mendeleef, b. Dalton, d. Lavoisier, d. Cavendish,
e. Priestley.

23. Which of the following men contributed least to the isolation of
argon as a new element?

   All the above contributed greatly and directly.

24. Select the partner Rayleigh had in work with inert gases of the air.

   a. Lord Kelvin, b. Sir William Crookes, c. Sir Humphrey

25. Writings of Cavendish regarding his work with nitrogen include,
"Having condensed as much as I could——only a small bubble of air
remained. So if there is any part of nitrogen of our atmosphere
that differs from the rest ______.

   a. It is surely negligible, b. It is not over 1/120
   part of the whole, c. It appears because of poor equip-
   ment, d. It must differ chemically, e. It must differ
   physically.

26. Chlorine was discovered in 1775 by a pharmacist who did chemical
experiments as a hobby. His name was ______.

   a. Priestley, b. Cavendish, c. Lavoisier, d. Dalton,
e. Scheele.

27. Berthollet hit upon the idea of using the bleaching action of
chlorine and ______.

   a. Became wealthy with royalties, b. Gave the process
to the French government, refusing profit, c. Formed a
partnership with a French industrialist, d. Formed his own company using the process, e. Gave the process to one of his friends in the textile industry.

28. The man who first liquified chlorine wrote to a friend in 1823, "I hope to be able to reduce many other gases to liquid form". He did and his name is listed below.


29. Fluorine was not isolated until 1886; by liquefying pure hydrogen fluoride, adding some potassium fluoride and at a temperature of -23°C passing an electric current through the mixture. Who did it first?


30. The particle known as the electron was discovered by _____.

   a. Roentgen, b. Lawrence, c. Fermi, d. Thompson, e. None of these.

31. Pierre and Marie Curie extracted radium from _____.


---

DIRECTIONS: Events listed in items (32) to (37) happened at a certain time. The period in history for each event is to be selected from the choices that follow: (One choice per item)

- a. 1915 to present time
- b. 1915 to 1944
- c. 1900 to 1914
- d. 1800 to 1899
- e. Before 1800

32. When was the term "molecule" introduced by Avogadro?

33. Fritz Haber worked out a commercial process for the synthesis of ammonia using nitrogen from air.

34. For the first time someone separated water into hydrogen and oxygen then explained what he had done.

35. Arrhenius tackled the problem of ionization.
36. Fermi produced the elements neptunium and plutonium.

37. Discovery of the electron.

38. Dalton announced his ideas about relative weights of atoms.

39. Discovery of the neutron.

40. Alchemists did most of their work ________.

41. Curie obtained a few crystals of a salt of a new element which they named radium.

42. William Roentgen discovered X-rays.

43. Rutherford bombarded various elements with helium nuclei (alpha particles) and got protons.

44. Franklin wrote about electricity almost (but not quite) in terms of the electron theory.

45. Chlorine was prepared as a free gas for the first time.

46. Einstein advanced the idea that matter and energy are different forms of the same thing.

47. Established the correct explanation of burning.

Jaffe has written, "The method that Lavoisier used in reaching an explanation of (this important chemical reaction) is an example of the scientific method." Then he lists six steps as a brief statement of the method. Answers to the next six questions are based on these steps.

DIRECTIONS: Answer the next six items by making one selection for each from the following choices:

   a. Formulation of a law from the tested theory.
   b. Formulation of a working theory based upon these facts.
   c. The testing of the working theory by experiments.
   d. Collection of all available facts related to a problem
   e. Not listed.

48. Pick the choice you think should be step #1 in the scientific method.

49. Step #2.

50. Step #3.
51. Step #4.
52. Step #5.
53. Step #6.

Now take the SECOND answer sheet and use it for the remainder of the test.
B. Test of Scientific Method

For Part II of the test select the one best answer.

1. The primary aim of science is to
   a. Refute religious or philosophical dogma, b. Discount old or archaic ideas, c. Substantiate the results of others, d. Seek the truth by means of analyzed observations.

2. The scientific method allows final interpretation to be based only on
   a. Current opinion, b. Speculation, c. Observed and analyzed data, d. Mores (customs) and traditions.

3. According to the scientific method, data should be interpreted by
   a. Everybody, b. The majority, c. Experts, d. The authorized.

4. The scientist should use as a means for making his decisions his own
   a. Emotions, b. Intelligence, c. Habits, d. Instincts.

5. To be scientific, one should
   a. Adopt the questioning attitude, b. Accept without verification the statement of others, c. Accept the statements that are claimed by others to be scientific, d. Accept the statements of those with whom one agrees.

6. The scientific method must include for the interpretation of the final solution of a problem the consideration of
   a. Only a few factors in order that the solution might become simple, b. The unknown factors, c. All the known factors, d. All observable, and essential factors.

7. The scientific worker should
   a. Discard all previous advancements of knowledge, b. accept purported authority as a tentative conclusion, c. Accept authority that is supported by usage of long stand, d. Accept authority that is supported by patriotic or religious feeling.

8. When one follows the scientific method, he should
a. Discredit all authority, b. Accept authority when the majority agree with it, c. Accept the statements of those whom he considers to be authorities until opportunity for verification is offered, d. Accept the statements of those who claim that they are authorities.

9. The worker in science must treat newly-discovered conclusions of other workers with

10. To be scientifically accurate an investigator should seek in the final solution of a problem the weight or importance of
   a. Only one unknown factor, b. All the pertinent factors, c. Only the constant factors, d. Only the variable factors.

11. According to the scientific method, a supposition is substantiated when the solution
   a. Is verified by observable data, b. Satisfied the previous opinions of the investigator, c. Appears to be logical, d. Agrees with custom.

12. Scientific conclusions must be treated as
   a. Absolute and changeless truths, b. Explanations subject to possible revisions, c. Authoritative pronouncements, d. Explanations of ultimate reality.

13. The ultimate aim of the scientific method is to
   a. Express phenomena in terms of verified natural laws, b. Overthrow conclusions that are well-established in the minds of the people, c. Verify what has already been discovered, d. Discover incidental facts.

14. In relation to the control group, the experimental group represents the normal group with
   a. None of the factors changed, b. All of the factors changed, c. All of exception of a certain changed factor, or set of related factors, which is being studied, d. Many changed factors chosen indiscriminately.

15. Which of the following does not belong in a list of steps of the scientific method?
a. The collection of all available facts related to a problem, b. Open-minded examination of these facts, c. Equal consideration given to tradition and facts, d. Testing a working theory by experiments.
C. Test of Ability to Draw Conclusions

Note: (Read directions carefully).

DIRECTIONS: In each of the statements below an experiment is described and some possible answers are suggested. Select the one which you think is the best conclusion on the basis of the facts presented.

16. When iodine is added to starch, a blue-black color is formed. Some iodine was added to milk, and the color became yellow. This shows that:
   a. Milk contains sugar, b. Milk contains starch, c. Iodine can not be used to test for starch in milk, d. Milk does not contain starch.

17. When an artery is cut the bleeding may be stopped by tying a tourniquet (a tight bandage) between the cut and the heart. This is evidence that:
   a. Blood in an artery is flowing away from the heart, b. Arterial bleeding is dangerous, c. When an artery is cut, it will bleed, d. Blood in the arms and legs flows downward.

18. A scientist was examining some tiny living cells under a microscope. By means of a delicate needle, he was able to cut apart each cell. He found that when he cut the cell through the nucleus both parts survived. When he cut through the cell away from the nucleus, the part which retained the nucleus lived, and the other part died. This shows that:
   a. The nucleus is an important part of the cell, b. Microscopic cells can be dissected, c. Microscopes are needed to study cells, d. All living things contain cells.

19. A student placed some fruit flies in a test tube, stoppered the test tube, and covered one half of it with black paper. When he placed a light near the test tube the fruit flies all came to the part which was not covered. This seems to show that:
   a. The fruit flies are attracted by light, b. All insects are attracted by light, c. The fruit flies were trying to get air, d. They were trying to escape through a hole in the stopper.

20. A famous scientist once discovered that when he made the gas nitrogen by one method, a certain amount always weighed 1.2505 grams. When he prepared it by another method, the same amount of nitrogen always
weighed 1.2572 grams. This would indicate that:

a. Nothing, since the results are close enough, b. The scales used for weighing were not sufficiently accurate, c. The nitrogen made by the second method was mixed with some heavier gases, d. The weight of the nitrogen changes from time to time.

21. A student measured the intensity of light which he received at various distances from a lamp and tabulated his results as follows:

<table>
<thead>
<tr>
<th>Distance from lamp</th>
<th>Intensity of light</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 feet</td>
<td>1 foot-candle</td>
</tr>
<tr>
<td>4 feet</td>
<td>4 foot-candles</td>
</tr>
<tr>
<td>2 feet</td>
<td>16 foot-candles</td>
</tr>
<tr>
<td>1 foot</td>
<td>64 foot-candles</td>
</tr>
</tbody>
</table>

His best conclusion is:

a. The greater the distance from the lamp, the less the light received, b. Doubling the distance from the lamp decreases the amount of light by one-fourth, c. Doubling the distance from the lamp increases the amount of light four times, d. The intensity of illumination is measured in foot-candles.

22. A spectroscope is an instrument which enables us to detect the different elements by means of the characteristic colored lines which they produce when heated. In 1868, a scientist studied the light given off by the sun with a spectroscope and discovered a series of colored lines which did not correspond with any element known on earth. This made him conclude that:

a. There was an element on the sun which had not been found on earth, b. The sun is extremely hot, c. The sun contains elements, d. The spectroscope is a useful instrument.

23. In 1781, William Herschel discovered the planet Uranus. Astronomers carefully calculated the path which this planet should follow around the sun, and other astronomers followed the movement of this planet with their telescopes. After 60 years, it was noticed that Uranus was actually farther from the sun than had been predicted. They knew that the force of gravity causes all objects to attract each other. This was evidence that:

a. The astronomers made their calculations incorrectly, b. The telescopes needed improvement, c. Another planet, farther from the sun, was attracting Uranus, d. Uranus is a planet and not a star.
D. An Experimental Scale

Note: (The items in Part IV of this test will not be scored "all right" or "all wrong". Read directions carefully).

DIRECTIONS: These are statements with which you may or may not agree. Well educated people do not all respond in the same way to some of these items.

Throughout Part IV of this test, items should be marked on your answer sheet with your one choice of A, B, C, D or E meaning that you:

A. Strongly agree (strongly approve)
B. Agree (approve)
C. Undecided
D. Disagree (disapprove)
E. Strongly disagree (strongly disapprove)

Example: (Most, but not all, people will strongly agree with the following statement.)

Brushing the teeth after each meal is better for prevention of tooth decay than not brushing the teeth.

A B C D E

Example: (Most, but possibly not all, people will strongly disagree with the following statement.)

People should not eat meat.

A B C D E

Example: If you cannot understand a statement or cannot make up your mind, answer:

A B C D E

READ EACH ITEM THOUGHTFULLY
24. Weather forecasts given by calendars and almanacs are absolutely
worthless.

25. Very few things ever happen without some cause.

26. If a new car were to be given away to the holder of a lucky number,
I should choose my number very carefully.

27. Beauty and brains seldom go together.

28. A father broke the hall mirror on his way to work; then that night
a car smashed into his as he made a left turn into his drive way.
Breaking the mirror had nothing to do with the other misfortune.

29. A man is stronger when he is angry or under emotional strain.

30. A brand of breakfast food advertised on TV must be better than a
brand not so well known.

31. If you look at a person's back long enough you can cause him to turn
around.

32. There is nothing so sacred that well trained men should not be
allowed to investigate and try to explain it.

33. The forces of nature act in an orderly way.

34. Cigarettes used by famous athletes and sportsmen must be better
for one's health than other brands of cigarettes.

35. All charm and good luck pieces are useless.

36. Jim beat Jane in swimming across the pool two times straight, and
therefore Jim is a better swimmer.

37. A well known naturalist reports that he has recently observed a
white crow in a flock of ordinary black ones. My reaction is that
the report might be true but not very likely to be.

38. When I push the light switch and nothing happens I can infer the
power is off in the main line.

39. Consider the statement "The brain of a person of high intelligence
weighs more than the brain of a person with low intelligence". The
idea is so logical it can be accepted as true without further
evidence.

40. A "soaring intellect and wide-ranging imagination" would be a help
to a person trying to work in a purely scientific manner.
1. A man who knows how to solve problems in a scientific manner will naturally try to solve all his problems in a scientific way.

2. The scientific method is so natural and logical it does not need to be taught to people. In other words, if I try to solve a problem thoughtfully, I will naturally be using the scientific method.

3. Your first "hunch" is probably best.

4. There is no place for "trial and error" in the scientific method.

5. Whenever doctors find a way to lick one disease, another comes along to take its place.

Note: (Underline material in following statements should be accepted as factual for purposes of this test. Continue to give your opinion about the remaining part of each item).

6. Botanists have catalogued 300,000 plants from all over the world. Chemists have intensely analyzed a dozen, especially corn and soy beans. We need a stepped-up search of all plant life for new foods, pharmaceuticals, and chemical products.

7. It is predicted that by 1970 American industry will have doubled its already tremendous need for water. Water is already in tight supply with expanded irrigation etc. Probably nothing can be done about this dilemma.

8. Astrologers can read a person's character and future in the stars.

9. It is possible that a ring around the moon is a sign of rain and the number of stars in the ring indicate how many days until the rain will come.

10. In its preoccupation with immediate, practical results, the United States is neglecting pure scientific research.

11. Astronomers have gotten terrific static when Jupiter crosses the path of a huge radio telescope they set up on a Maryland farm. It is possible that a study of this static would help astronomers pin down the effect of sun spots on weather.

12. If the groundhog sees his shadow on Groundhog Day (Feb. 2) it is a better than average chance there will be six weeks of continued winter.

13. Illness is not punishment for doing wrong.

14. It would be scientific to investigate a "hunch".

END
E. Chemistry Assignment Sheet

(Unless otherwise stated, page numbers are from "New World of Chemistry" by Jaffe. Assigned questions are under the heading "Group A").

Introduction to Course

1. Note about metric system.
2. Instructions about notebooks.
   a. Laboratory section
   b. Biography section
3. Assessment for current literature.
4. Laboratory aprons.
5. Assignment sheets.
6. Get signatures for some biographic reports, particularly Becher and Bacon.

UNIT I "MATTER"

Assignment No. 1 - (1) In text, (2) Demonstration (Sulfuric acid on sugar.), (3) Report on Chemistry of the Ancients - particularly, Aristotle (Includes an outline to serve as a model for students).

Assignment No. 2 - (1) Pages 8-14, Questions 7-12 p. 23, (2) Discuss symbols, page 88, (3) Election of class president.

Assignment No. 3 - (1) Finish chapter and questions in group A, (2) Experiment No. 1 - drill.

Assignment No. 4 - (1) Laboratory experiment No. 3, (2) Biography - Becher.

Assignment No. 5 - (1) Start review for test over Unit I, (2) Biography - Francis Bacon.

Assignment No. 6 - (1) Complete review for test over Unit I, (2) Start locker inventory, (3) Biography - Lavoisier.

Assignment No. 7 - Test over Unit I.

UNIT II "OXYGEN"

Assignment No. 8 - (1) Discuss test, (2) Introduce Unit II "Oxygen", (3) Pages 25-31; Questions 1-13 pp. 44-45, (4) Complete locker inventory.
Assignment No. 9 - Laboratory experiment "Oxygen" (formal write up).

Assignment No. 10 - (1) Pages 32-38; Questions 13-24; page 45, (2) Biography - Priestley.

Assignment No. 11 - Finish Unit II and questions.

Assignment No. 12 - Test over "Oxygen".

UNIT III "HYDROGEN"

Assignment No. 13 - (1) Discuss test over "Oxygen", (2) Introduce Unit III "Hydrogen", (3) Pages 47-52; Questions 1-8 page 59.

Assignment No. 14 - (1) Pages 52 - end of unit, (2) Biography - Cavendish.

Assignment No. 15 - Laboratory experiment "Hydrogen".

Assignment No. 16 - (1) Demonstration "Reduction of Cu O", (2) Informal write up, laboratory Unit No. 6.

Assignment No. 17 - Review of Unit III.

Assignment No. 18 - Test over "Hydrogen".

UNIT IV "WATER"

Assignment No. 19 - (1) Discuss test over unit III, (2) Introduce "Water".

Assignment No. 20 - (1) Pages 61-66; Questions 1-9 page 71, (2) Biography Edward Morley.

Assignment No. 21 - (1) Demonstration of Electrolysis of water, (2) Informal write up of laboratory Unit No. 7.

Assignment No. 22 - Pages 67-73; questions 10-20 page 74.

Assignment No. 23 - Finish questions pages 74-75.

Assignment No. 24 - Review for test over Unit IV.

Assignment No. 25 - Laboratory experiment No. 8. Demonstration and informal write up.

Assignment No. 26 - Test over "Water".

UNIT V "ATOMS AND FORMULAS"

Assignment No. 27 - (1) Discuss test over "Water", (2) Introduce Unit
Assignment No. 28 - (1) Pages 76-80; questions 1-10, (2) Biography - Dalton.

Assignment No. 29 - (1) Finish unit on "Atoms" including questions, (2) Biography - Beethollet.


Assignment No. 31 - (1) Pages 85-90; write practice formulas page 90, (2) Biography - Sir Humphry Davy.

Assignment No. 32 - (1) Drill, (2) Biography - Alchemists.

Assignment No. 33 - (1) Study page 91 to end of unit, questions as assigned, (2) Biography - Berzelius.

Assignment No. 34 - Review of "Atoms and Formulas".

Assignment No. 35 - Test over "Atoms and Formulas".

Assignment No. 36 - Second test over "Atoms and Formulas".

UNIT VI "EQUATIONS"

Assignment No. 37 - (1) Discuss test over "Atoms and Formulas", (2) Introduce new unit "Equations".

Assignment No. 38 - (1) Pages 114-118; Write balanced equations page 118, (2) Biography - Mendelief.

Assignment No. 39 - Equation balancing drill.

Assignment No. 40 - (1) Finish unit in text, (2) Questions 1-9 page 121.

Assignment No. 41 - Equation balancing drill.

Assignment No. 42 - (1) Questions 10-25 page 122, (2) Review "Chemical Equations".

Assignment No. 43 - Test "Chemical Equations".

UNIT VII "ATMOSPHERE"

Assignment No. 44 - (1) Discuss "Chemical Equations", (2) Introduce new unit "The Atmosphere".

Assignment No. 45 - (1) Pages 96-101; questions 1-10 page 112, (2)
Biography - Rayleigh.

Assignment No. 46 - (1) Pages 102-108; questions 11-20 page 112, (2) Biography - Sir William Ramsay.

Assignment No. 47 - Demonstrations with liquid air.

Assignment No. 48 - Finish unit; questions 21-32.

Assignment No. 49 - Review unit, "The Atmosphere".

Assignment No. 50 - Unit test.
F. Instructions for Biographies

1. Select a chemist from the suggested list or submit the name of a chemist for class acceptance.

2. The written report may be in outline form or complete sentence form. It must be in ink and otherwise follow the Ames High School's "Minimum Essentials in English".

3. A copy of the report should be "handed in" after oral presentation to the class.

4. Reporters should aim at a 10 minute report in the class.

5. Opportunity should be allowed for questions from the class members (this can be in addition to the ten minutes).

6. Class members will take notes from the report, as far as subject matter permits, according to the following outline:

   NAME OF SCIENTIST (Subject of Report)

   Name of Reporter  
   Date of Report  

   I. Important years.  
      b. Years of important contributions to science.  

   II. Brief story of life (personal items help).

   III. Contributions to science.

   IV. Emphasis upon problems the scientist faced and the way he solved them.

   V. Important sources of information used by the reporter.

7. Notes from the biographical reports should be filed in chronological order. Use either the date of birth of the scientist or the year of the greatest scientific contribution for the point of reference.

8. Ordinarily, the notes will be ready for inspection within one day after the reports are given in class. They are to be in ink and follow "Minimum Essentials".
A. Findlay, A Hundred Years of Chemistry, 1948.
S. J. French, The Drama of Chemistry, 1937.
J. C. Gregory, A Short History of Atomism, 1931.
J. C. Gregory, A History of Combustion, 193-.
E. J. Holmyard, The Great Chemists, 1929.
E. J. Holmyard, Makers of Chemistry, 1931.
J. Read, Prelude to Chemistry, 1937.
M. E. Weeks, Discovery of the Elements, 1945.

W. R. Akroyd, Three Philosophers (Lavoisier, Priestley, Cavendish), 1935.
C. Borth, Pioneers of Plenty. The Story of Chemurgy, 1939.
E. Curie, Madame Curie, 1938.
S. J. French, Torch and Crucible. The Life and Death of Antoine Lavoisier, 1941.
B. Harrow, Eminent Chemists of our Time, 1920.
B. Jaffe, Crucibles, the Story of Chemistry. 1939.
D. McKie, Antoine Lavoisier, 1953.
F. R. Moulton, Liebig and After Liebig, 1942.
W. Ramsay, Essays Biographical and Chemical, 1908.
H. Roscoe, John Dalton and the Rise of Modern Chemistry, 1895.
W. Tilden, Famous Chemists. The Men and Their Work, 1921.
R. Vallery-Adot, Life of Pasteur.
J. P. Baxter, Scientists Against Time, 1946. (Am. Wartime Research)
B. Jaffe, Men of Science in America, 1944.
D. Stimson, Scientists and Amateurs. 1948.
D. Struik, Yankee Science in the Making, 1948.
H. Thomas and D. L. Thomas, Living Biographies of Great Scientists, 1941.
G. Wilson, The Human Side of Science, 1929.
E. Yost, Modern Americans in Science and Invention, 1941.
American Women in Science, 1943.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Biographer</th>
<th>Subject</th>
<th>Biographer</th>
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<tr>
<td>Aristotle and others</td>
<td>Scheele</td>
<td>Einstein</td>
<td>Seaborg</td>
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<tr>
<td>Becher</td>
<td>Thompson</td>
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<td>Francis Bacon</td>
<td>Crookes</td>
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<td>Rutherford</td>
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<td>Cavendish</td>
<td>Franklin</td>
<td>Haber</td>
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<td>Van't Hoff</td>
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<td>Faraday</td>
<td>Bohr</td>
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<td>Kelvin</td>
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I. Summarization of Data

\[ Y_0 = \text{Achievement in Fundamentals of Chemistry Score} \]

\[ Y_1 = \text{Achievement in Men and Events Score} \]

\[ Y_2 = \text{Achievement in Scientific Method Score} \]

\[ Y_3 = \text{Scientific Attitude Score} \]

\[ Y_4 = \text{Shift in Kuder Scientific Interest Score} \]

\[ Y_5 = \text{Achievement in Science Activities and Ambitious Score} \]

\[ X_1 = \text{IQ Most Recently Recorded in Student's Cumulative Record} \]

\[ X_2 = \text{Geometry Mark} \]
J. Sums with Totals and Subtotals

<table>
<thead>
<tr>
<th>Group</th>
<th>Subtotal</th>
<th>Total</th>
<th>Subtotal</th>
<th>Total</th>
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<tbody>
<tr>
<td>Boys (E)</td>
<td>( Y_0 = 3657.4 )</td>
<td></td>
<td>( Y_4 = 140 )</td>
<td></td>
</tr>
<tr>
<td>Girls (E)</td>
<td>( Y_0 = 2305.8 )</td>
<td></td>
<td>( Y_4 = 144 )</td>
<td></td>
</tr>
<tr>
<td>Boys (C)</td>
<td>( Y_0 = 3396.2 )</td>
<td></td>
<td>( Y_4 = 137 )</td>
<td></td>
</tr>
<tr>
<td>Girls (C)</td>
<td>( Y_0 = 2066.0 )</td>
<td></td>
<td>( Y_4 = 102 )</td>
<td></td>
</tr>
</tbody>
</table>

\( Y_0 = 11425.4 \)   \( Y_4 = 543.3 \)

| Boys (E) | \( Y_1 = 1458 \) |           | \( Y_5 = 814 \) |           |
| Girls (E)| \( Y_1 = 962 \) |           | \( Y_5 = 443 \) |           |
| Boys (C) | \( Y_1 = 1217 \) |           | \( Y_5 = 794 \) |           |
| Girls (C)| \( Y_1 = 670 \) |           | \( Y_5 = 447 \) |           |

\( Y_1 = 4307 \)   \( Y_5 = 2498 \)

| Boys (E) | \( Y_2 = 925 \) |           | \( X_1 = 5713 \) |           |
| Girls (E)| \( Y_2 = 542 \) |           | \( X_1 = 3476 \) |           |
| Boys (C) | \( Y_2 = 949 \) |           | \( X_1 = 5637 \) |           |
| Girls (C)| \( Y_2 = 576 \) |           | \( X_1 = 3480 \) |           |

\( Y_2 = 2992 \)   \( X_1 = 18306 \)

| Boys (E) | \( Y_3 = 5509 \) |           | \( X_2 = 254 \) |           |
| Girls (E)| \( Y_3 = 3338 \) |           | \( X_2 = 167 \) |           |
| Boys (C) | \( Y_3 = 5738 \) |           | \( X_2 = 283 \) |           |
| Girls (C)| \( Y_3 = 3430 \) |           | \( X_2 = 178 \) |           |

\( Y_3 = 18015 \)   \( X_2 = 882 \)
K. Sums of Squares and Cross-Products

\begin{align*}
Y_0^2 &= 83569.52 & Y_0X_1 &= 1317208.1 \\
Y_1^2 &= 121490.1 & Y_1X_1 &= 1498162 \\
Y_2^2 &= 57188 & Y_2X_2 &= 2111916 \\
Y_3^2 &= 2048809 & Y_3X_1 &= 2068774 \\
Y_4^2 &= 17227 & Y_3X_2 &= 100624 \\
Y_5^2 &= 39804 & Y_4X_1 &= 286664 \\
X_1^2 &= 2111916 & Y_4X_2 &= 13966 \\
X_2^2 &= 39804 & Y_5X_1 &= 1317208.1 \\
Y_0X_2 &= 65117.8 & Y_5X_2 &= 102513 \\
Y_1X_2 &= 24615
\end{align*}